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COMPARISON OF SAMPLERS TO MEASURE INHALABLE PARTICULATE

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Ontario

Ministry
of the
Environment

The Honourable
Andrew S. Brandt
Minister

Gérard J. M. Raymond
Deputy Minister

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John Hicks and Denis Corr
ONTARIO MINISTRY OF THE ENVIRONMENT

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SUMMARY

It is only particles smaller than 10-15 microns aerodynamic diameter which can penetrate to the human lung. Since the protection of human health is a prime reason for measuring and controlling airborne particles, the Ministry of the Environment should have the capability to monitor inhalable particulate levels and composition. The Atmospheric Contaminants and Research Planning Unit of the Air Resources Branch, together with the Central Region and Laboratory Services Branch, have compared inhalable particulate sampling systems with standard samplers at an urban Toronto sampling site.

The respiratory system can be broken down into the nasopharyngeal region (NP), the tracheobronchial region (TB), and the pulmonary region (P), each of which has different particle size deposition characteristics, mechanisms of removal and cleaning methods. Susceptibility to damage is greatest in the pulmonary region (due to the long residence time of particles) and smallest in the nasopharyngeal region.

The aerodynamic diameter of a particle of unit density is a factor determining in which region of the respiratory system particles will deposit. There are no sharp cut-offs in particle size deposition curves for different regions but some general statements can be made. For example, for mouth breathing, particles of diameter 10 to 15 um. aerodynamic diameter or larger deposit in the NP and do little harm, particles less than 10 um. can deposit in the TB and particles of 3 to 5 um. or less tend to deposit in the P where they can do the greatest harm.

Studies of airborne particles in the environment have shown a bimodal size distribution similar to that noted in the deposition characteristics found in the lung. A coarse fraction greater than 2.5 um. is generally found to be from natural sources caused by the breakdown of larger masses. The fine fraction is composed of particles less than 2.5 um. in aerodynamic diameter and usually

emanates from man-made sources. The residence time in the air is longer for these particles than for coarse particles and they can travel greater distances in airstreams.

In the past, the standard sampler for airborne particle monitoring has been the HiVol sampler which samples large volumes of air through a glass fibre filter mat. Although the sampler is sturdy, it has been found to have many shortcomings in its design as well as in its effectiveness. In order to remedy sampling inconsistencies caused by the original gabled roof of the standard HiVol, as well as to limit collection to those particles under 15 microns, HiVols can be retrofitted with size selective inlet heads.

The dichotomous sampler, modelled after inertial virtual impactors which fractionate particles according to their aerodynamic characteristics, was designed to sample only those particles less than 15 um. in diameter and to fractionate them into the coarse or the fine mode.

A standard HiVol, a Size Selective Inlet HiVol (S.S.I. HiVol) and four dichotomous samplers were evaluated in an urban Toronto location from October 1980 to June 1982. The data showed a significantly greater amount of scatter in the results of the HiVol concentrations than in the less than 15 um. fraction sampled by dichotomous samplers. When the dichotomous total is divided into fine and coarse fractions, the correlation with the HiVol further decreased. Correlation between the HiVol and the coarse fraction was poor and between the HiVol and the fine fraction was even worse (declining from 0.72 to 0.47).

Whereas the S.S.I. HiVol correlates well with the total dichotomous concentrations, the correlation diminishes when broken down into coarse and fine dichotomous. Although total inhalable particulate may be interpolated from HiVol readings using the relation equation, only through direct measurement with dichotomous samplers can the total inhalable particulate concentration be resolved into coarse and fine loads.

In conclusion, the S.S.I. attachment did not seem to give a significant advantage over the HiVol since the values measured by the S.S.I. could be adequately predicted from HiVol data. The Coefficient of Haze monitor was found to give a real-time approximation (hourly) of fine particulate. A sulphate artifact which may double the actual sulphate values and which is of a magnitude great enough to affect T.S.P. measurements was apparent on glass fibre filters analyzed.

Size fractionation of the environmental aerosol at 2.5 um. in aerodynamic diameter provides relative toxicity parameters to health officials, as well as aiding the analyst in source apportionment in local settings. It will also give additional information about heavy pollution episodes. The additional, better focussed information available from dichotomous samplers therefore makes it worthwhile to extend this sampling technique to different air quality situations in different regions of Ontario. The information gathered in this way can also be used to assist in setting an inhalable particulate standard for Ontario.

INTRODUCTION

The Atmospheric Contaminants and Research Planning Unit of the Air Resources Branch, together with the Central Region and Laboratory Services Branch, have evaluated the technology and methodology of inhalable particulate measurement systems at an urban Toronto sampling site. A standard HiVol, a Size Selective Inlet HiVol, a coefficient of haze monitor, and four dichotomous samplers were evaluated from October 1980 to June 1982. This report, the objective of which is to inform and enable Ministry officials to arrive at some conclusions regarding the future state of inhalable particulate sampling in Ontario, outlines the data and statistical evaluation of the measurements.

1.0 LITERATURE REVIEW

The HiVol sampler has been the primary instrument of measurement of airborne particulate matter for almost twenty years (Robson and Foster, 1962). Using a filter matrix of glass fibre, ambient aerosols are measured as Total Suspended Particulate (TSP) and analyzed for nitrate, sulphate, and a number of metal contaminants. The sampling system has become the basis for particulate standards throughout most of North America.

However, the HiVol/glass fibre particulate sampling method has been found to have a number of drawbacks which limit its value in quantifying atmospheric aerosols.

Artifact sulphate and nitrate (Lee and Wagman (1966), Spicer, et al. (1978)) have been found to be present on glass fibre filters through reactions with SO_2 and NO_x gases. The extent of the artifact varies and cannot be definitely quantified, however, the artifact appears greater in industrialized regions. The artifact may be great enough to not only give unreasonably high levels to sulphate and nitrate but may also boost TSP measurements.

The HiVol is also prone to passive particulate deposition while the sampler is in the standby mode. Most monitoring agencies sample on a regular three or six day basis, thereby changing the filter in between sampling days. The filter is then prone to wind blown dust deposition which may modify TSP and elemental measurements (Lizzarga-Rocha (1976), Swinford (1980)).

It has been found through wind tunnel testing that the HiVol's upper size limit varies as wind speed and direction fluctuate. The collection efficiency of large particles (greater than 20 um. aerodynamic diameter) is not constant and consistency in measurement could only be gained with a properly designed inlet head (Wedding et al. (1977), McFarlane and Ortiz (1980)).

To more accurately measure the inhalable particulate (I.P.), various sampler inlets have been designed to collect only particles 15 um. and less. This was based upon respirable deposition measurements of mouthbreathing individuals (Miller et al. 1979). The samplers described in this report are a product of this recommendation. However, in 1981 an ad hoc group of the International Standards Organization (I.S.O.) recommended that a 10 um. cutpoint would be in better agreement with measured values of inhalable deposition. Those guidelines are commonly referred to as PM10. The U.S. Environmental Protection Agency (E.P.A.) is expected to set a PM10 inhalable particulate standard in the summer of 1983. The Ontario Ministry of the Environment is also working toward defining inhalable particulate.

Dichotomous and HiVol particulate levels have been compared by a number of researchers since 1980. The studies are attempts to generate data which will be used in the setting of a standard by the E.P.A. The studies also act as field tests for the recently available dichotomous samplers.

Most studies attempt to define an IP/TSP ratio for their locality. Generally the ratio varies daily depending upon meteorological and emission conditions. However urban areas generally have an IP/TSP ratio of 0.6. Areas of greater fugitive emissions will have a lower ratio, and industrial regions are generally greater than the 0.6 mean ratio. This is characteristic of the finer particulate size distribution sampled from industrial sources.

To accurately compare the two measurements the relationship should be described by a linear equation instead of a ratio. The linear equation will account for positive biases (artifacts and passive loading) of the SSI and the HiVol as described previously. Witz (1982) in comparing SSI and dichotomous IP, showed that most of the positive bias of the SSI could be credited to sulphate and nitrate artifacts. Watson (1982) noted the dichotomous 15 um. inlet head lost sampling efficiency in higher winds.

The EPA found dichotomous sampler mass concentrations were 10 to 15% less than those measured by S.S.I. samplers (Pace et al. 1981). The extent of the sulphate and nitrate artifacts tends to be greater in the industrialized eastern states than the west.

Other researchers found various dichotomous sampling sites to have very different measurements. Miller (1980) found the fine dichotomous fraction to be nearly constant throughout an urban airshed, although the coarse fraction varied with height of sampler. The average coarse concentrations were greatest at street level and decreased inversely with height. Suggs et al. (1981) used a number of dichotomous samplers to generate spatial correlations depicting the sampler performance with respect to the environment. The correlations were all high if the stations were not situated near an industrial site. Grantz (1981) similarly used samplers to quantify particulate levels about an integrated iron and steel making complex. Good correlations appeared between samplers, providing emission plumes were spatially well dispersed when sampling.

A survey of IP/TSP ratios as measured by dichotomous and HiVol samplers shows a range of values from 0.43 as described by Miller (1980) at a position close to a major road to 0.70 of Watson (1981) taken from an urban commercial area. Most urban IP/TSP ratios are in the 0.6-0.7 range.

2.0 THE RESPIRATORY SYSTEM

Mechanisms in the respiratory passages filter and cleanse the air of particles which are inhaled through the mouth or nose. Different sized particles deposit in different parts of the respiratory tract. Airborne particles are removed by:

1) inertial impaction
2) filtration
3) gravitational settling
4) Brownian diffusion to bronchial walls and
5) condensation and coagulation

These deposition mechanisms operate due to the presence of tubing curvatures, nasal hairs, branching of passages and an ever decreasing diameter within the breathing passages.

The respiratory system can be broken down into three major sections (see Figure 1), each of which has different particle size deposition characteristics, mechanisms of removal and cleansing methods (Task Group on Lung Dynamics, 1966). The three sections are as follows: Nasopharyngeal Region; Tracheobronchial; and Pulmonary.

2.1 Nasopharyngeal Region (NP)

This region is made up of the nasal and oral passages, plus the pharynx and larynx. Deposition is facilitated by impaction on the roof and walls of the throat and nose, and filtration by nasal hairs. Removal of foreign matter is accomplished by sneezing, coughing, swallowing and, in the nose, by mucociliary clearance. Mucociliary clearance is the removal of foreign matter on a thin layer of mucus which is swept along by fine, constantly beating cilia. Clearance times are usually a matter of minutes. Susceptibility to ill effects is normally slight for environmental levels of contaminants except for sensitive or allergic individuals.

2.2 Tracheobronchial Region (TB)

The tracheobronchial region is made up of a number of progressively branching passages starting at the laryngeal cavity and ending in the terminal bronchioles. The trachea is a tube leading from the laryngeal cavity, followed by branches called the bronchi. Throughout the tracheobronchial region, deposition mechanisms are facilitated by branching and curving of the passages, thereby promoting turbulence and impaction. The slower laminar air flow further out in this region, together with reduced bronchus diameter, promotes particle deposition by gravitational settling. Removal is by flow of mucus along the ciliated walls until deposited in the throat for ingestion. The clearance time for particles in this region is ten minutes to twenty-four hours, depending on deposition site. Susceptibility to damage is greater in this region than in the nasopharyngeal region due to the longer residence times of the particles. Sensitive individuals may suffer asthma attacks due to deposition in the tracheobronchial region.

2.3 Pulmonary Region (P)

This region consists of small bronchioles and alveolar clusters which form a diffusional membrane for gas transport between the bloodstream and the air. Air moves in this region by diffusional transport and deposition usually takes place by diffusion to the walls. Removal of deposited particles is facilitated by macrophages which move the particles to the ciliated airways or lymph nodes. Clearance time of insoluble particles in this region can range from months to years. Due to the long residence time of particles and the delicate nature of the alveolar structure, susceptibility to damage is greatest here. A relatively small mass of particulate matter is deposited in the pulmonary region because of the extremely efficient protection and clearance mechanisms of the respiratory tract.

2.4 Size Dependence and Regional Deposition

Particle deposition studies have shown particles to deposit in the respiratory system according to their aerodynamic diameter (the corresponding diameter of a particle of unit density with the same aerodynamic characteristics). As a rough approximation, particles of diameter 10 to 15 um. or greater deposit in the nasopharyngeal region and do little harm, particles of less than 10 um. usually deposit in the tracheobronchial region and particles 3 to 5 um. or less tend to deposit in the pulmonary region where they can do the greatest harm (see Figure 2). Some of these values tend to vary depending on the type of breathing (whether by mouth or nose), inhalation flow rate, the pattern of breathing, etc. In general, most inhaled particles will deposit somewhere in the respiratory system. Size fractionating particulates into these size ranges gives the scientist a clearer view of the pollution danger to public health. (Lippman, 1977)

3.0 PARTICULATE SAMPLING

3.1 Bimodal Character of Airborne Particulates

> "The coincidence of the size transition at 2.5 um. in both the particle production and health effects is a prime motivation for developing a dichotomous sampler."
>
> B.Y. Loo, Lawrence Berkeley
> Laboratory, California

Studies of airborne particles in the environment have shown a bimodal size distribution similar to that noted in the deposition characteristics found in the lung. (Whitby and Cantrell, 1975) A coarse fraction greater than 2.5 um. is generally found to be from natural sources caused by the breakdown of larger masses. The particles are usually generated by local sources and, due to their greater susceptibility to gravitational settling, they have a short residence time in the atmosphere. Their chemical nature is similar to that found in crustal minerals and they contain large amounts of silicon, aluminum, calcium, chloride, etc. (see Figure 3).

The fine fraction is composed of particles less than 2.5 um. in aerodynamic diameter and is generally found to emanate from man-made sources. Emissions of vapours, gas, and nuclei from industrial stacks and exhausts condense and accumulate to form sub-micron particles which undergo coagulation into clusters of fine particles. Their residence time in the air is longer and they can travel greater distances in airstreams than the coarse particles. The fine mode is often responsible for poor visibility on hazy days. After further coagulation, they may settle, wash out or diffuse onto buildings or vegetation. They are usually composed of elemental carbon, organics, metals, sulphates and nitrates.

It is clear that the bimodal nature of particulate size is important with respect to source, public health, residence time in the atmosphere, transport and pollution control.

3.2 The HiVol

In the past, the standard sampler for airborne particulate monitoring has been the Hivol sampler. It samples large volumes of air (1600 m^3 per day, but can be up to 2400 m^3/day) through an 8" x 10" glass fibre filter mat. Although the sampler is sturdy, it has many shortcomings in its design.

The gabled roof inlet is prone to sampling biases. (McFarlane et al. 1979) The concentration of particulate measured will vary with the angle of the intake slots to the wind direction (see Figure 4) and as the wind velocity is increased, the bias becomes more pronounced. In addition, the Hivol does not have a definable upper particle size cut point. As the sampling efficiency of the HiVol sampler varies with wind direction, the collection efficiency of large particles tends to vary with wind speed (see Figure 5). The sampler will show an 80% sampling effectiveness for 30 um. particles in a 2 km./hr. wind but only 40% effectiveness during 24 km./hr. winds.

The glass fibre mats are known to be high in some impurities and can also cause formation of artifact sulphate upon the filter. (Lee and Wagman (1966), Spicer et al. (1978)) This artifact not only makes accurate sulphate measurements impossible but also may be of a magnitude great enough to significantly increase T.S.P. measurements. Artifact nitrate formation on glass fibre filters has been measured by Witz (1982). This West Coast Basin study noted average value of 7.7 ug/m^3 for artifact nitrate on conventional HiVol glass fibre filters.

3.3 The Size Selective Inlet (S.S.I.)

No sampler has a perfectly sharp cutoff at a given particle size, i.e. there will always be some larger particles sampled and there will never be 100% sampling efficiency for particles smaller than the cutoff size. For the purpose of the following discussion, the particle size cutoff is defined as that particle size at which the collection efficiency is 50%.

HiVols can be retrofitted with size selective inlet heads to remedy sampling inconsistencies caused by the original gabled roof and to specify the particle sizes sampled. The round inlet shape allows unbiased sampling from any direction. Upon entering the inlet, the particulates are drawn through a series of baffles which separate out particles greater than 15 um. in aerodynamic diameter on the basis of their greater settling velocity. Therefore, only "inhalable" particulates (less than 15 um. A.D.) are sampled by the HiVol when the size selective inlet (S.S.I.) is attached (see Figure 6). The S.S.I. is now available with a 10 um. cut point.

The HiVol, once retrofitted with the S.S.I., is not prone to biases in wind direction, maintains an established cut point in winds of up to 25 km./hr., and samples at close to 100% efficiency through all conditions. Although sulphate artifacts are still apparent when glass fibre filters are used, teflon-coated fibre filters have been used with some success. (Dann, 1983)

3.4 The Dichotomous Sampler

The dichotomous sampler was modelled after inertial virtual impactors which fractionate particles according to their aerodynamic characteristics, simulating the behaviour of the particle in the lung. Developed from the cascade centripeter, it was designed to sample those particles less than 15 um. in aerodynamic diameter and to separate them into the coarse (2.5 to 15 um.) or the fine fraction (less than 2.5 um.). The size-segregated aerosol is filtered by a chemically inert teflon membrane filter. The aerosol on the filter can be analyzed later in the laboratory. (Loo, 1976) The dichotomous sampler has a much lower sampling rate than the Hi-Vol, sampling 24 m^3 in each 24-hour period.

3.4.1 Inlet Head

The inlet head was designed to allow particles smaller than 15 um. into the sampler. Particles greater than this are too prone to gravitational settling to enter the inlet tube. The head is cylindrically symmetric to provide uniform sensitivity to particulates, independent of the wind direction (see Figure 7). The inlet only allows particles which are capable of entering the respiratory system into the sampler. A new inlet head which samples particles smaller than 10 um. is available but has not yet been tested by MOE.

3.4.2 Virtual Impactor

From the inlet head, the sampled particles pass down through a vertical tube to the virtual impactor, which separates the particles into their respective coarse and fine modes. In this regard it simulates a conventional impactor but instead of an impactor plate, it creates a void relative to the inertial flow. Larger particles are carried into this void because of their greater inertial momentum. Once the aerosol is aerodynamically fractionated into two air streams, it is collected on teflon filters (see Figure 8).

3.4.3 Automation

The degree of automation varies with the make of the sampler. All have programmable timing mechanisms and feedback control loops to maintain a steady pressure drop across the impactor and filters. This feedback system is essential for the maintenance of the correct size fractionation as weather conditions change or the filter resistance increases with particulate load. Some models can change samples automatically either at a pre-specified time or when the flow resistance of the sample is too great to maintain established fractionating cutpoints. Under Canadian weather conditions, all samplers appear to function as designed.

4.0 SAMPLER EVALUATION

4.1 Sampler Models Tested

A standard HiVol, a Size Selective Inlet Hivol and four dichotomous samplers were evaluated in an urban Toronto location. A Coefficient of Haze tape sampler was also operated at the same site. Two dichotomous samplers required manual changing of filters, while the other two were automated. The samplers were run from October 1980 to June 1982. Twenty-four hour samples were collected either every three or six days depending on the sampling schedule. The sampling data are provided in Tables 1.0 through 1.5 (pages 43 through 48).

The sampling site (#31001) on the roof of 67 College Street was utilized until its demise in June, 1981. A new site (#31104) was constructed on the roof of 26 Breadalbane Street. Although the samplers were located 2 storeys higher at the College St. site and the locations are three blocks away from each other, both sites appear to be subject to the same type of urban Toronto pollution. Missing sampling data are due to the change in site (2 1/2 months) and various breakdowns in the different samplers.

The four dichotomous samplers evaluated were:

MODEL 3000 DICHOTOMOUS SAMPLER (VIRTUAL IMPACTOR)
ANDERSON SAMPLERS' INC. ATLANTA, GEORGIA

SERIES 244 DICHOTOMOUS SAMPLER (VIRTUAL IMPACTOR)
SIERRA INSTRUMENTS, CARMEL VALLEY, CALIF.

SERIES 245 AUTOMATIC DICHOTOMOUS SAMPLER (VIRTUAL IMPACTOR)
SIERRA INSTRUMENTS, CARMEL VALLEY, CALIF.

AUTOMATED DICHOTOMOUS PARTICULATE SAMPLING SYSTEM
BECKMAN INSTRUMENTS, FULLERTON, CALIF.

MODEL 7000 INHALABLE PARTICLE SIZE SELECTIVE INLET
ANDERSEN SAMPLERS INC., ATLANTA, GEORGIA

"Coefficient of Haze" (COH) tape sampler data were obtained from MOE files for the Toronto site 31104. Although the Beckman sampler was scheduled to be operated, difficulties in maintaining regular operation made it impossible to include it in our regular sampling program. Therefore, the limited Beckman sampler data are not listed in the report.

4.2 Weighing and Handling Experiments

Dichotomous sample filters were weighed prior to and after exposure at the Air Resources Branch. HiVol filters were similarly weighed at the Laboratory Services Branch. A number of experiments were implemented to determine optimum weighing and sample handling practices. Some operational errors can be minimized with proper equipment and control, but other errors such as occasional leakage of particulates through the snap ring seals must be considered as inherrent errors until the technology is improved. This was apparent with all dichotomous samplers tested.

The dichotomous filters were stored in a constant humidity chamber and weighed in an atmosphere of approximately 40% R.H. Although teflon filters are hygroscopic, the particulate loading could absorb moisture from the air. By maintaining constant humidity conditions during weighing, there is less tendency for readings to fluctuate.

The dichotomous samples were weighed with a microbalance because of the relatively small loadings on these filters. A Cahn Model 25 automatic electrobalance was used. An electrobalance was chosen because previous experience had shown that a beam type microbalance was extremely sensitive to vibration, required frequent maintenance and was difficult to operate. No such difficulties were encountered with the electrobalance. The balance was sensitive to one microgram which was necessary when weighing the loadings found on dichotomous filters. Prior to weighing, the sample filters were irradiated by Po 210 source to neutralize static charges, which could interfere with the balance precision. Samples were stored horizontally in petri dishes to prevent particles falling off the filter before weighing and analysis were completed.

An intercomparison of blank filter weights between Ontario Ministry of the Environment and Environment Canada revealed excellent accuracy. Of 10 filters weighing 90-100 mg., the maximum weight difference between the two laboratories was 7 ug. All others were less than 5 ug in weight change. These differences are quite acceptable when the particulate loading would average approximately 400 ug per filter. However greater differences in weight were apparent with particulate laden filters.

In an initial experiment to test the effects of humidity, particulate weights were found to vary ± 5% over the humidity range of 5-50% R.H. It was noted that the absorption of atmospheric moisture by the sample is relatively fast and the balance sample pan area and the storage room must be kept at a uniform humidity. The fine particulate samples tended to fluctuate more than the coarse samples. The weight variability at constant humidity was consistently within ±3% of the average weight. Other studies have shown the fine mode to be generally about 70% soluble compared to approximately 45% soluble for coarse particulates. Therefore the fine load will vary in weight more than the coarse when humidity is not constant.

The particulate samples often had a slight static charge before weighing which could increase the load weight up to 3%. The static charge could be eliminated by irradiating the sample with a small Po^{210} source. This effectively eliminated any weighing fluctuations due to static electricity.

The presence of volatile constituents in the particulate loading was difficult to measure. A number of loaded filters were weighed and then stored in an oven at 40°C for one week. The filters were then allowed to re-equilibrate to room humidity and weighed again. The experiment was repeated with temperatures at 50°C. The results showed some loss of sample, presumably due to evaporation of volatiles. The greatest loss was after the storage at 50°C. Although these filters never lost more than 4% of their load weight it is possible that samples from other areas would have a higher volatile content and be more prone to loss. How much of the volatiles were lost during sampling is unknown.

Due to the inert flat membrane surface of teflon filters it has been suspected that particles are easily lost when the filters are transported. A test was performed to attempt to quantify the relative loss of particulate loading when the filter is roughly handled. Individual filters were enclosed in petri dishes and dropped against hard surfaces. The weight change after the rough handling was approximately 10% loss of load weight for coarse particulate and less for fine particulate. Field studies with dichotomous samplers have relied upon careful handling of the samples by hand. Flat boxes with tip-n-tell gauges may be a good investment when regional samplers are deployed.

4.3 Analysis of Samples

Loaded teflon filters were first analyzed by wavelength dispersive x-ray (Siemens SRS Sequential X-ray Spectrometer) fluorescence spectrometry until an energy dispersive XRF unit (ORTEC TEFA III) was acquired by Laboratory Services Branch. This latter instrument is capable of rapidly and non-destructively analyzing the filters for 34 elements.

The analyte detection limits of the instrument are dependent upon the mass loading of the filter. The appropriate detection limits for an average sample are:

ug/filter		ug/m^3 air	ug/filter		ug/m^3 air	ug/filter		ug/m^3 air	ug/filter		ug/m^3 air
Mg	0.1	0.004	Ti	0.24	0.01	Ga	0.01	0.0004	Zr	0.6	0.03
Al	0.24	0.01	V	0.06	0.003	Hg	0.02	0.0008	Pd	0.03	0.001
Si	0.30	0.01	Cr	.036	0.02	As	0.18	0.008	Ag	0.06	0.003
P	0.12	0.005	Mn	.004	0.0002	Se	0.06	0.003	Cd	0.6	0.03
S	1.1	0.046	Fe	0.12	0.005	Br	0.12	0.005	In	0.1	0.004
Cl	0.3	0.01	Ni	.06	0.003	Pb	0.3	0.01	Sn	0.1	0.004
K	0.18	0.008	Cu	.06	0.003	Rb	0.06	0.003	Sb	0.2	0.008
Ca	0.24	0.01	Zn	0.12	0.005	Sr	0.06	0.003	Ba	3.0	0.13
						Y	0.02	0.0008	La	0.7	0.03

The detection limits are given as ug/filter, i.e. the minimum amount of analyte necessary to be on the filter to induce a signal, as well as the equivalent airborne concentration.

5.0 DATA ANALYSIS

The data were analyzed with a view to determining whether existing Ministry samplers could be used to determine inhalable particulate levels, and if not, which other methods might be used. Thus correlations were investigated between HiVol or COH values and the results from HiVol S.S.I. and various dichotomous samplers, both coarse and fine fractions.

Data analysis was accomplished using the Statistical Analysis System (SAS) utilizing the Downsview I.B.M. computer facilities. Graphic representations of the data collected are provided in Figures 9 through 25. Sample statistics are included in Table 2 and correlation coefficients between samplers are presented in Table 3.

Statistical correlations between daily HiVol TSP measurements and Size Selective Inlet (S.S.I.) concentrations were very good (corr.=0.940) (see Figure 9). The collection of particulates greater than 15 um. by the HiVol is apparent in the slope of the curve (m = 1.32). Therefore, the measurements of the S.S.I. are always lower than those of the HiVol. The I.P./T.S.P. or S.S.I./HiVol ratio was 0.72. The S.S.I. measures only Inhalable Particulate (I.P.). S.S.I. may be estimated from HiVol measurement by using the relation equation

HiVol = 1.32 S.S.I. + 5.7.

There was greater scatter (corr. = 0.816) when the results of the HiVol concentrations were compared with the less than 15 um. fraction measured by an average of the dichotomous samplers (see Figure 10). When the dichotomous total is divided into fine and coarse fractions (Figures 11 and 12), the correlation with the HiVol further decreased. (Coarse: corr. = 0.72, Fine: corr. = 0.47) The Dichot/HiVol ratio was is 0.62 for this urban site.

Whereas the Size Selective Inlet retrofitted HiVol (S.S.I.) correlates well (0.87) with the total dichotomous concentrations (see Figure 13), when broken down into coarse and fine fractions, the correlation is poorer for the coarse fraction alone (0.75) and worse again for the fine fraction (0.53) (see Figures 14 and 15). The ratio of coarse to fine particulate is not static and varies daily, which is exemplified by the total, coarse and fine comparisons (see Figures 16, 17 and 18). Although total inhalable particulate as measured by dichotomous sampler may be interpolated from HiVol readings by using the relation equation, HiVol = 1.21 (I.P. Dichot) + 22.5 (Fig. 10), the coarse and fine loads cannot. Only through direct measurement with dichotomous samplers can this be achieved. Figures 19 through 24 inter-compare the three models of dichotomous samplers used throughout the survey. In general, the agreement between the different samplers is good, both for fine and coarse fractions, even though there are the inevitable outliers in the results.

In Figure 25 the Coefficient of Haze (COH) was compared to the dichotomous fine fraction since it was expected that haze could be largely attributed to fine particles. However, only fair correlation (0.75) was found between these two measurements and one could not be interpolated from the other. It is noteworthy that this correlation result is not simply due to a few outliers but is due to a fairly even distribution of scatter.

In graphically comparing samplers using glass fibre filters (HiVol and the S.S.I.) to the dichotomous total measurements on teflon filters (e.g. Figure 10 and Figure 13, a y-intercept factor is always prominent. Upon closer evaluation, it was possible to attribute at least some of the y-intercept factor to the presence of sulphate artifacts on the glass fibre filters. The average sulphate concentration measured by dichotomous samplers was 6.6 ug/m^3 whereas the size selective inlet measured sulphate as 13.1 ug/m^3. This artifact, formed by SO_2 reacting with the filter matrix, not only over-estimates aerosol sulphate measurements but is also of a magnitude great enough to significantly increase TSP measurements. The inert teflon filters do not undergo any apparent reactions with the aerosol. The presence of sulphate artifacts on glass fibre filters has been well researched in the past. In this study, sulphate measurements on glass fibre filters generally doubled those measured on teflon filters thereby significantly raising the particulate load weight on the glass fibre samples. Nitrate was not measured on dichotomous filters in this study.

Energy dispersive x-ray analysis of the dichotomous filter pairs revealed many elements to be characteristic of one particular size. Whereas silicon, calcium, aluminum, iron and chloride are predominantly found in the coarse fractions, sulphur, nickel, arsenic, lead and bromine are usually found in the fine fractions. The elements of the coarse mode are those found in crustal minerals and appear to come from larger masses which are broken down to coarse particles. In contrast, the elements of the fine mode are characteristic of those chemical compounds released from combustion in the form of hot gases and nuclei. Through the process of condensation and agglomeration, these nuclei become bundles and strands of spheres which usually maintain an aerodynamic diameter of less than 2.5 um. It is expected that this size-dependent character can be used both as a tool for source apportionment as well as for calculating the rate of dispersion of the different aerosols. Although 36 elements are measured by energy dispersive x-ray analysis, many have concentrations too low to warrant attention (see Figures 26, 27 and 28).

Figure 29 is a plot of the particulate concentration (ug/m^3) during a pollution episode in downtown Toronto. The aerosol concentrations over three days were measured by both a HiVol and a dichotomous sampler. The dichotomous sampler would automatically change samples when particulate loadings became too heavy to sample consistently (i.e. pressure drops across the filters were becoming too great to maintain the 2.5 um. cut-point between fine and coarse flows). The concentration trends vary between the two samplers. For example, the HiVol shows a downward trend by Nov. 14 while in fact the fine particulate (most injurious to those with respiratory illnesses) is still increasing. The greater settling velocity of the coarse particulate and the greater than 15 um. aerosol might account for its declining concentration while the fine particles would persist in the atmosphere.

6.0 CONCLUSIONS

1. In practice, the Size Selective Inlet attachment does not give a significant advantage over the HiVol, since the values measured by the S.S.I. can be adequately predicted from HiVol data.

2. The total inhalable particulate concentration can be approximated from HiVol measurements using a linear relationship. The dichotomous sampler should, however, be used to measure the coarse (2.5 to 15 um.) particulate matter ("bronchial" deposition) and the fine (less than 2.5 um.) particulate matter (pulmonary). The numerical relationship between total inhalable particulate and T.S.P. is site specific and will vary depending upon the regional particulate sources.

3. Dichotomous samplers presently available will not give hourly concentrations, so coefficient of haze measurements (COH) will continue to be used for "real-time" control action during pollution episodes. It is worth noting that the correlation between COH and fine (less than 2.5 um) particulate is 0.75, which is better than the HiVol-COH correlation used to date for abatement action.

4. A sulphate artifact which increases actual sulphate values is apparent on glass fibre filters. The artifact is large enough to affect T.S.P. values. No measurements were made of nitrate during this study.

5. Size fractionation of the environmental aerosol at 2.5 um. in aerodynamic diameter not only provides the analyst with an estimation

of the pulmonary and bronchial particulate deposition but, upon chemical analysis, may also be used to provide relative toxicity parameters to health officials.

6. Size fractionation provides the analyst with information for source apportionment studies in localized settings and may be utilized to characterize heavy pollution episodes.

The Ontario Ministry of the Environment is purchasing eight Andersen-Sierra Automatic Dichotomous samplers with 10 um. cutpoint inlet heads for field trials across the Province. For use in remote areas, automatic sample changers are necessary and Andersen-Sierra now make the only available automatic dichotomous sampler. The new samplers will be used in conjuction with existing sampling equipment to determine I.P./T.S.P. ratios in different areas and to generate size-fractionated particulate data for monitoring and abatement use. It is expected that improved analytical power of the dichotomous sampler will be implemented in source-receptor pollution modelling methods.

ACKNOWLEDGEMENTS

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Fig. 1 THE RESPIRATORY SYSTEM

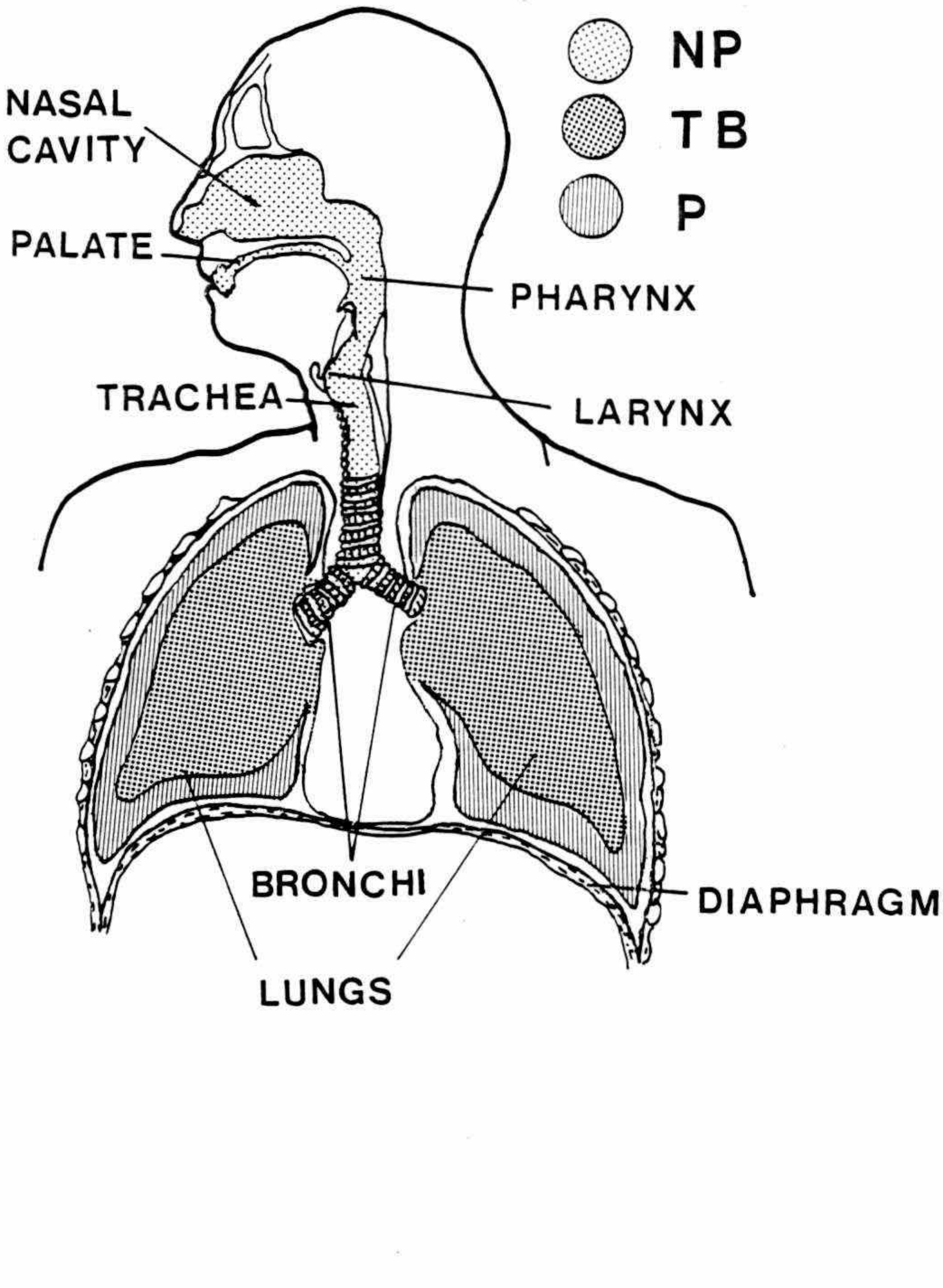

FIGURE 2 TOTAL AND REGIONAL DEPOSITION OF INHALED PARTICLES IN THE HUMAN RESPIRATORY TRACT, BASED ON ORAL BREATHING

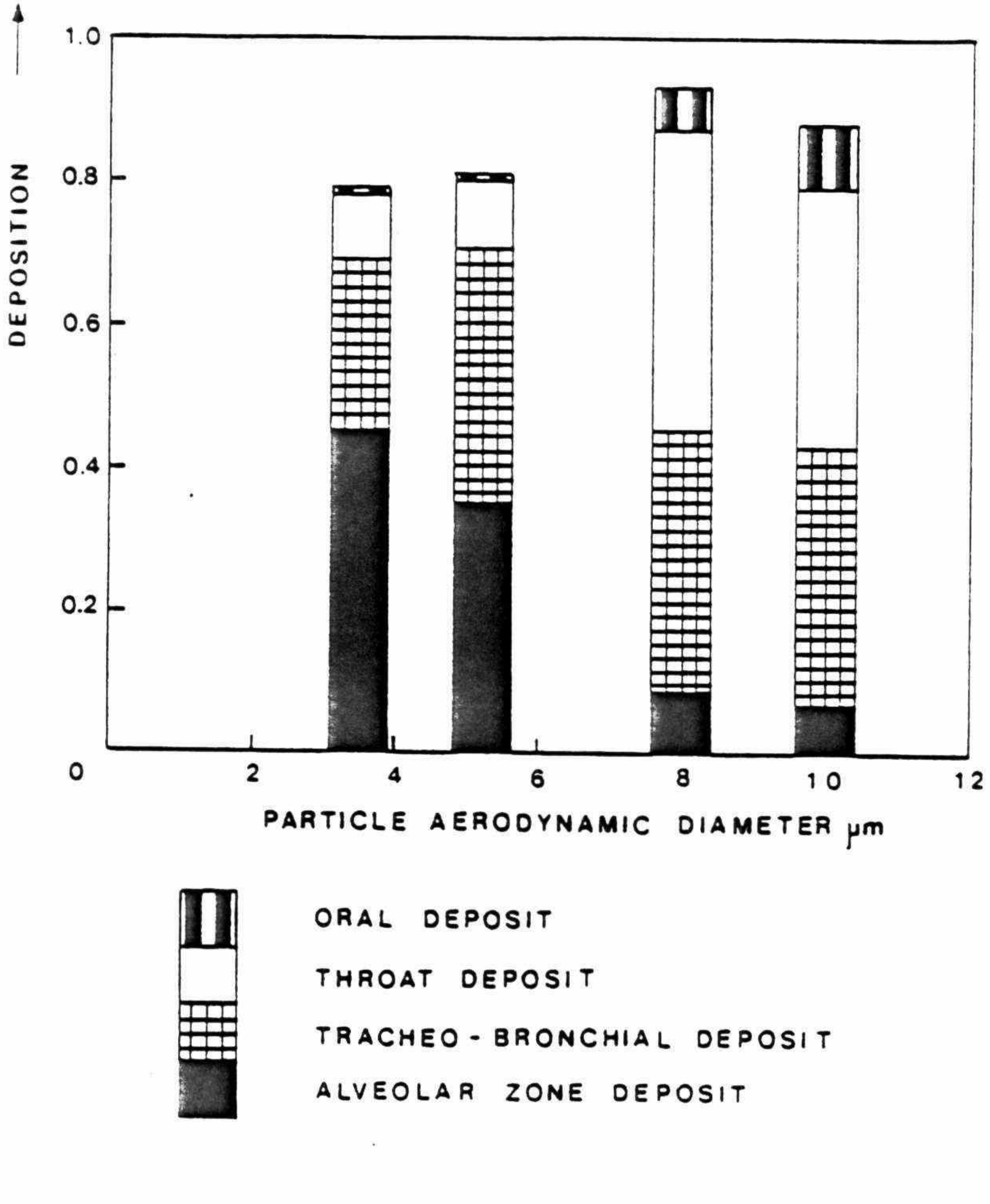

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Fig. 3

THE MAJOR CHEMICAL SPECIES IN ATMOSPHERIC AEROSOLS FALL INTO DIFFERENT SIZE GROUPS

NORMALLY FINE (2.5 UM)	NORMALLY COARSE (2.5 UM)	FOUND IN BOTH FRACTIONS	VARIABLE (BUT SOMETIMES SHOWING A FINE PARTICLE MODE)
$SO_4^=$	Fe	NO_3^-	Zn
C (SOOT)	Ca	Cl^-	Cu
	Ti		Ni
ORGANICS (CONDENSED VAPOURS).	Mg		Mn
Pb	K		Sn
NH_4^+	$PO_4^=$		Cd
As	Al		Sb
Se	C (POLLEN, SPORES PLANT PARTS)		
H^+			

Fig. 4

THE SAMPLING EFFECTIVENESS OF THE HI-VOL VARIES WITH WIND DIRECTION

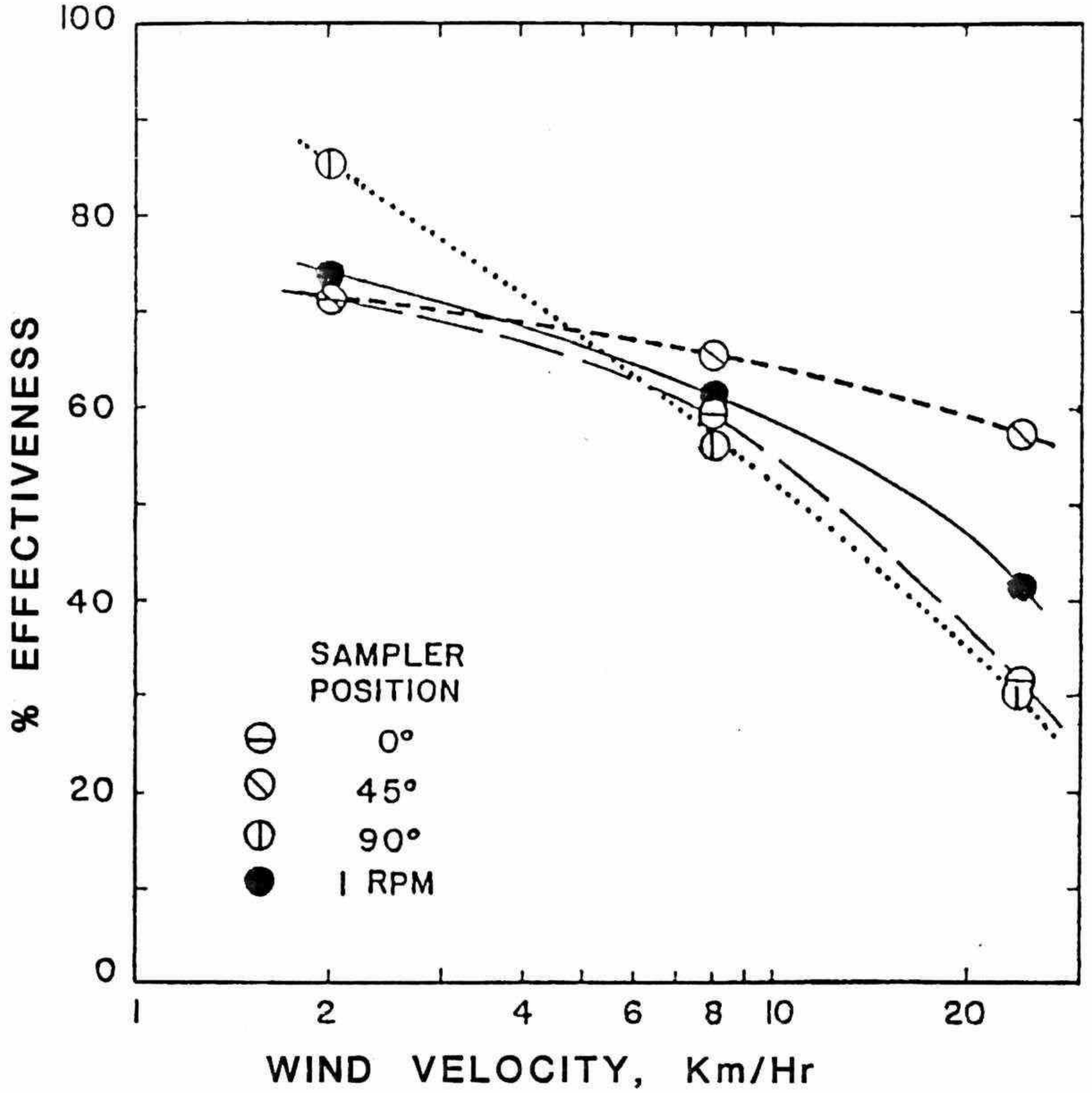

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Fig. 5

THE HI-VOL SAMPLER DOES NOT HAVE A DEFINED UPPER SIZE LIMIT

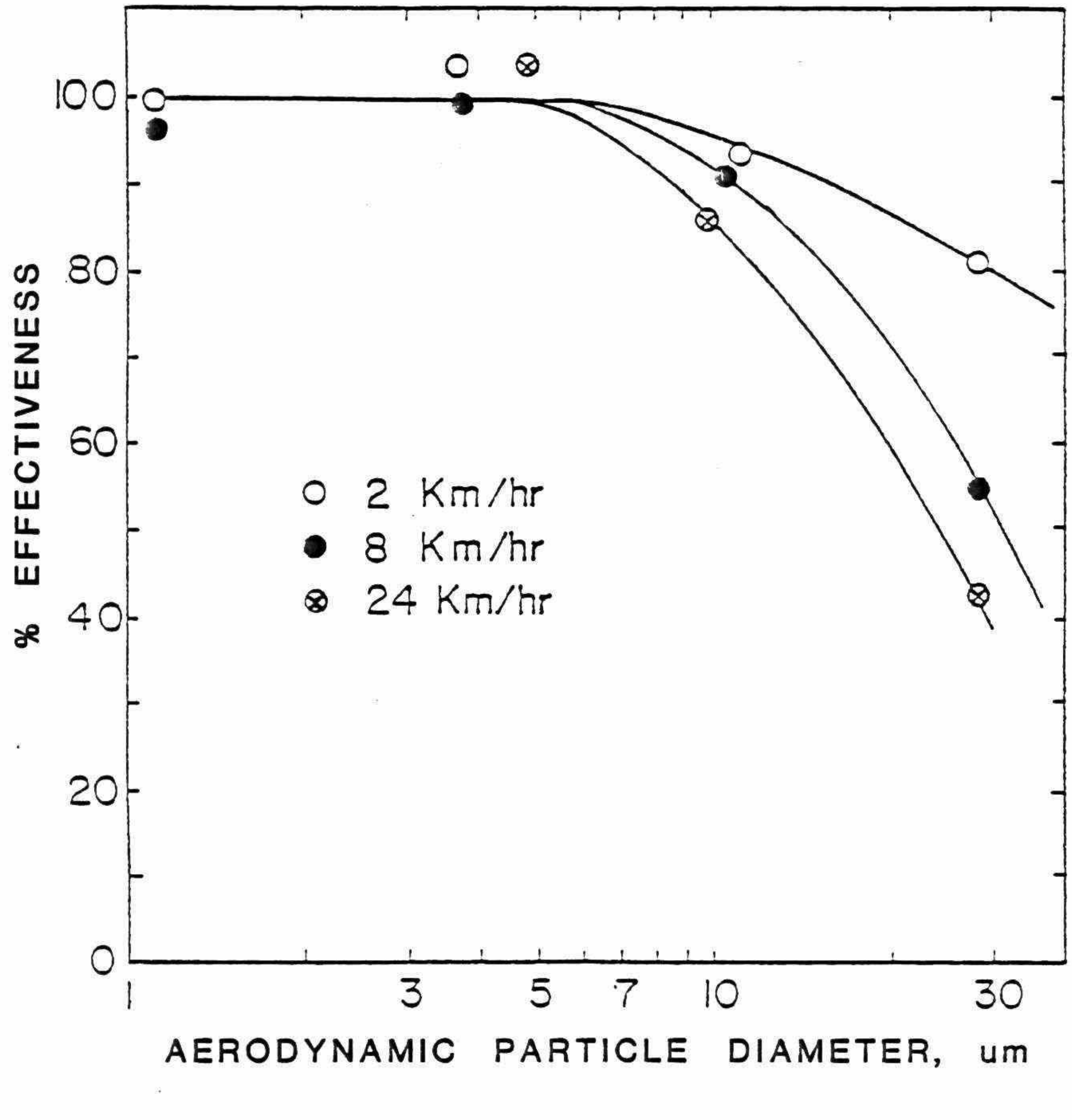

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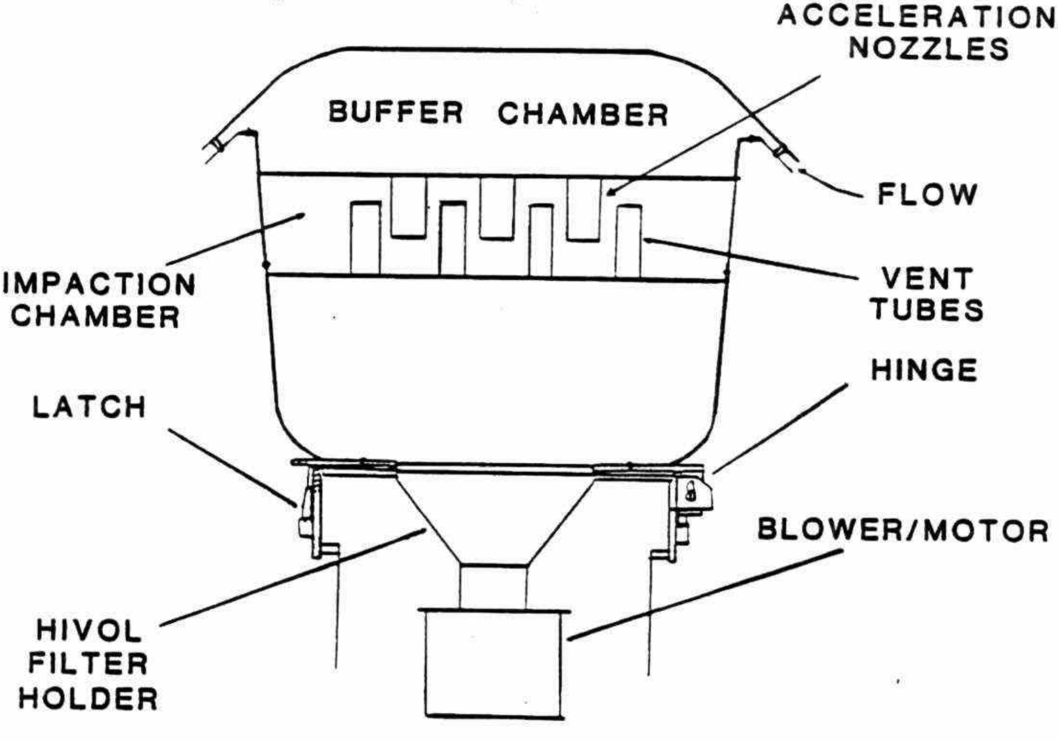
Fig. 6

SIZE SELECTIVE INLET
MODIFIED HIVOL SAMPLER (SSI)

-COLLECT PARTICULATES
< 15 um.
ON GLASS FIBRE FILTERS

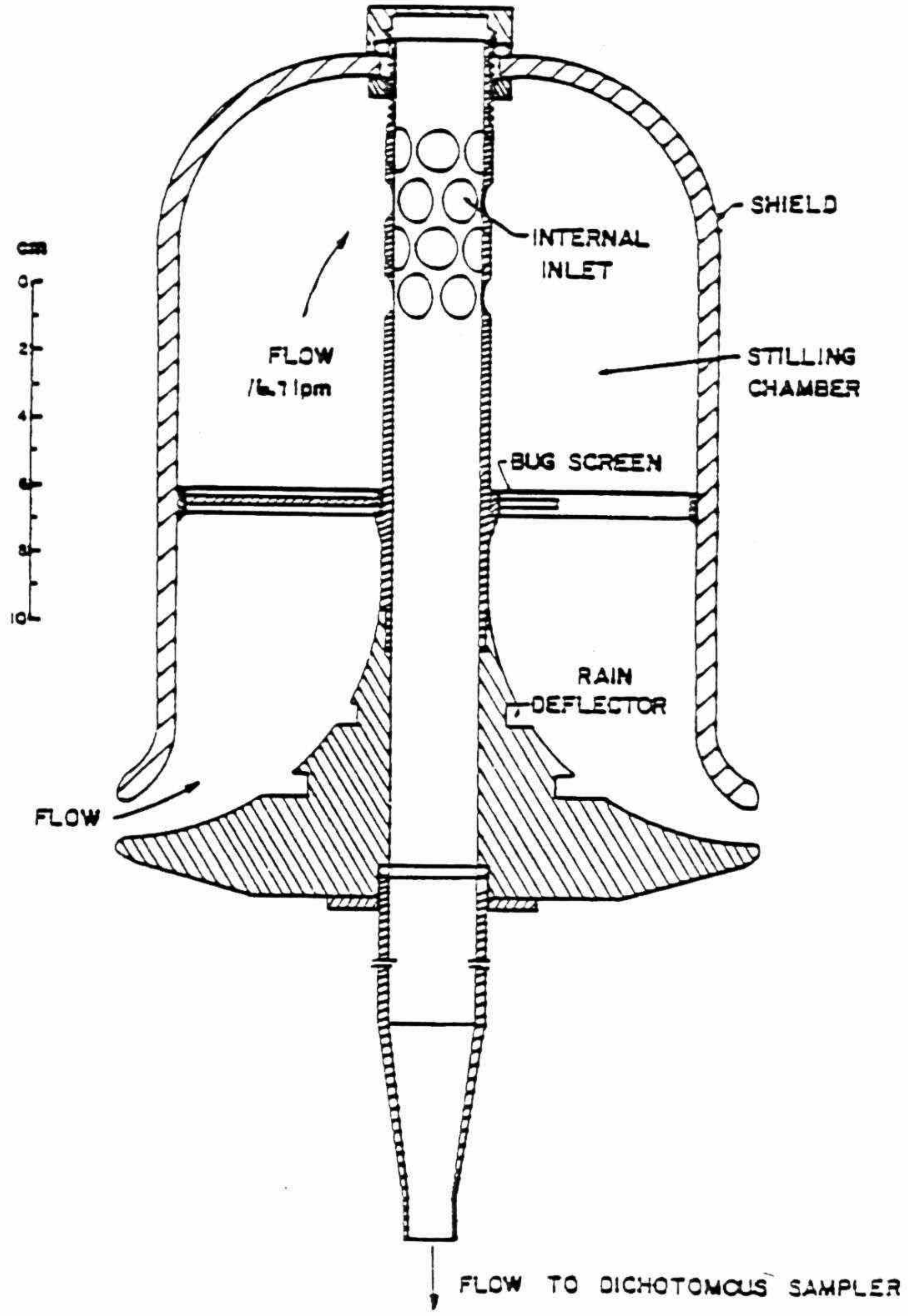


Andersen Samplers Inc., Model 7000
Operating Manual, 1979.

Fig. 7

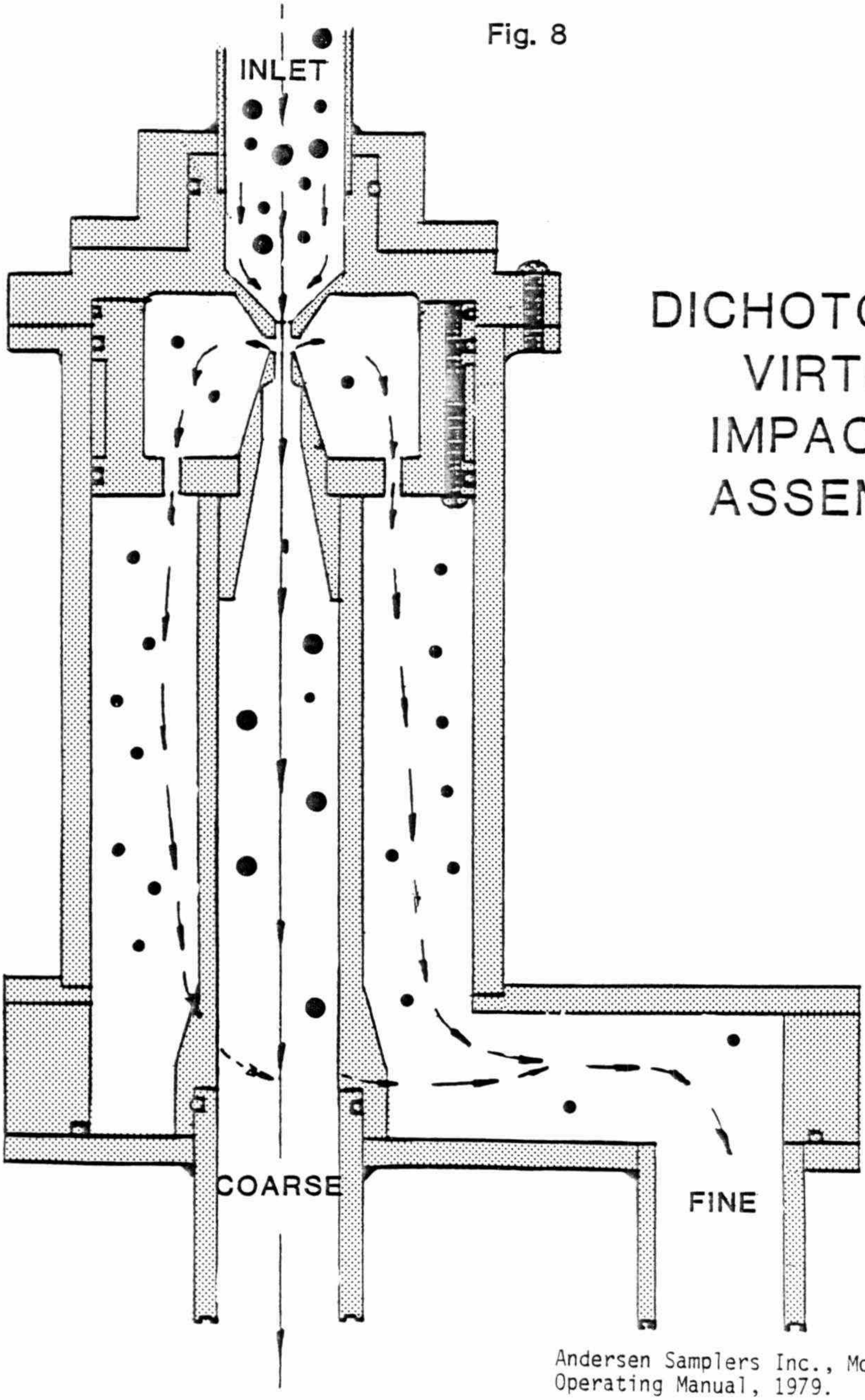
DICHOTOMOUS AEROSOL INLET HEAD

ALLOWS ONLY PARTICULATES <15 um.



Andersen Samplers Inc., Model 3000
Operating Manual, 1979.

Fig. 8



DICHOTOMOUS
VIRTUAL
IMPACTOR
ASSEMBLY

Andersen Samplers Inc., Model 3000
Operating Manual, 1979.

Fig. 9

HIVOL VS SIZE SELECTIVE
INLET HIVOL CONCENTRATIONS

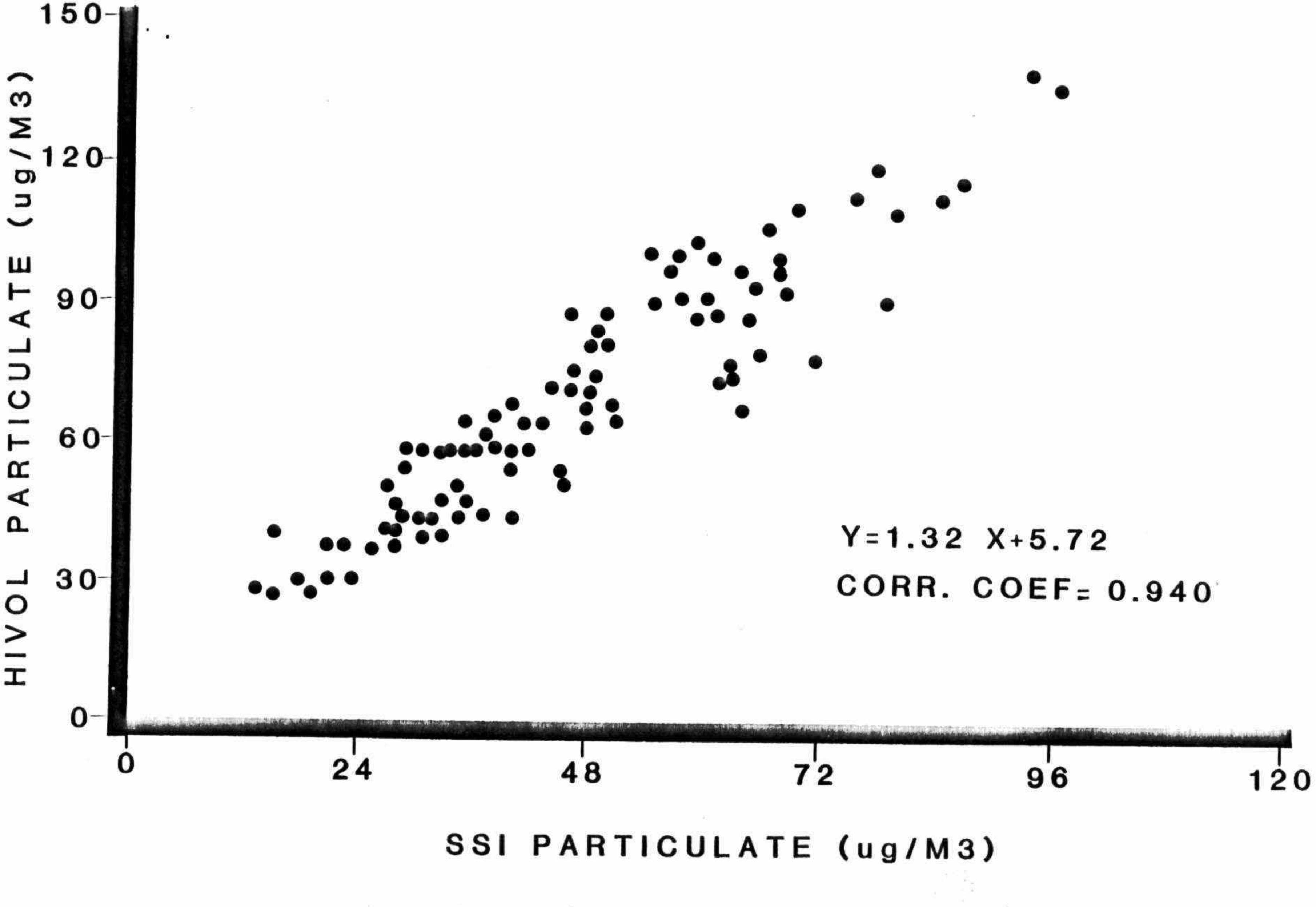


Fig. 10

HIVOL VS TOTAL DICHOTOMOUS CONCENTRATIONS

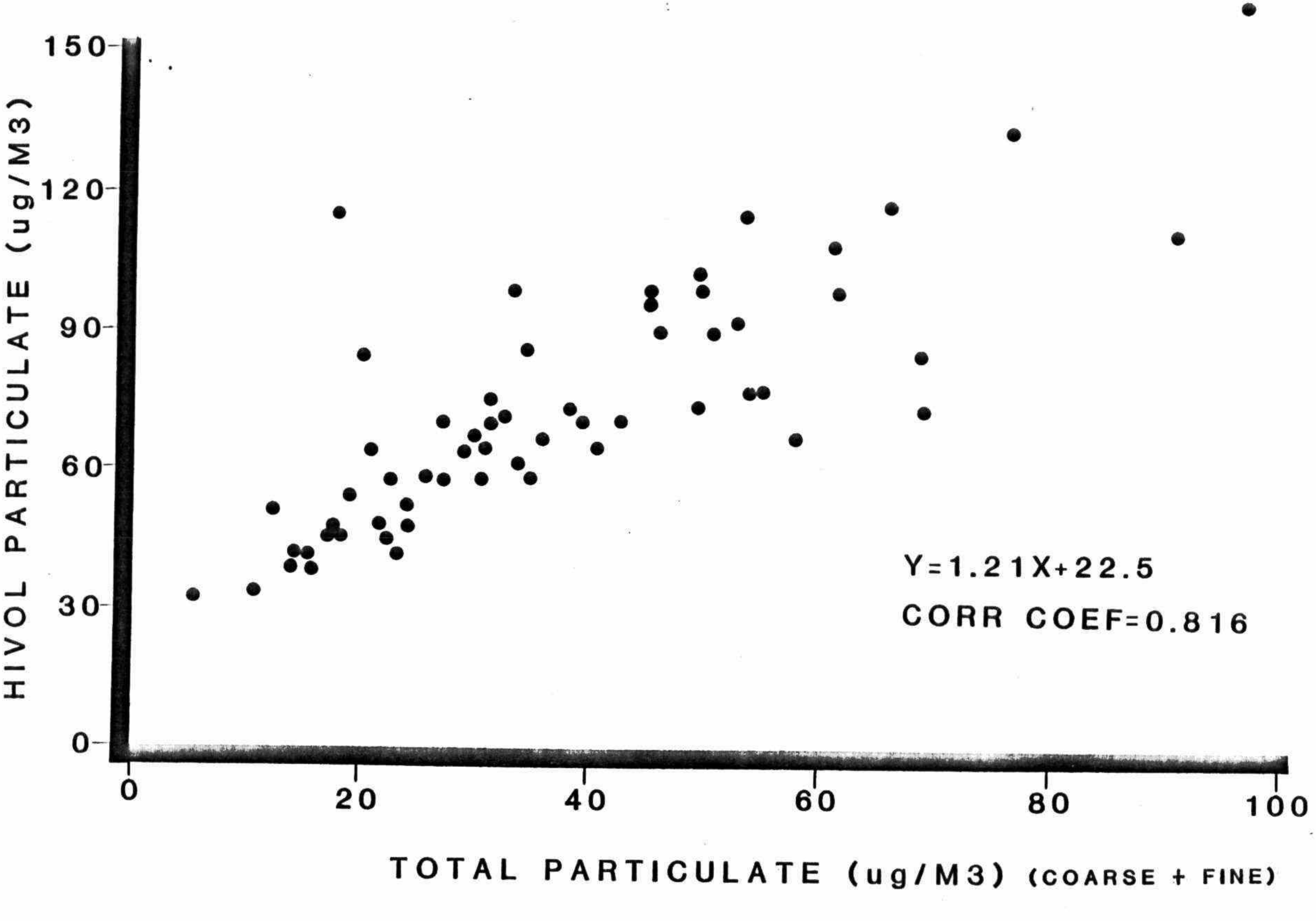


Fig. 11

HIVOL VS COARSE DICHOTOMOUS CONCENTRATIONS

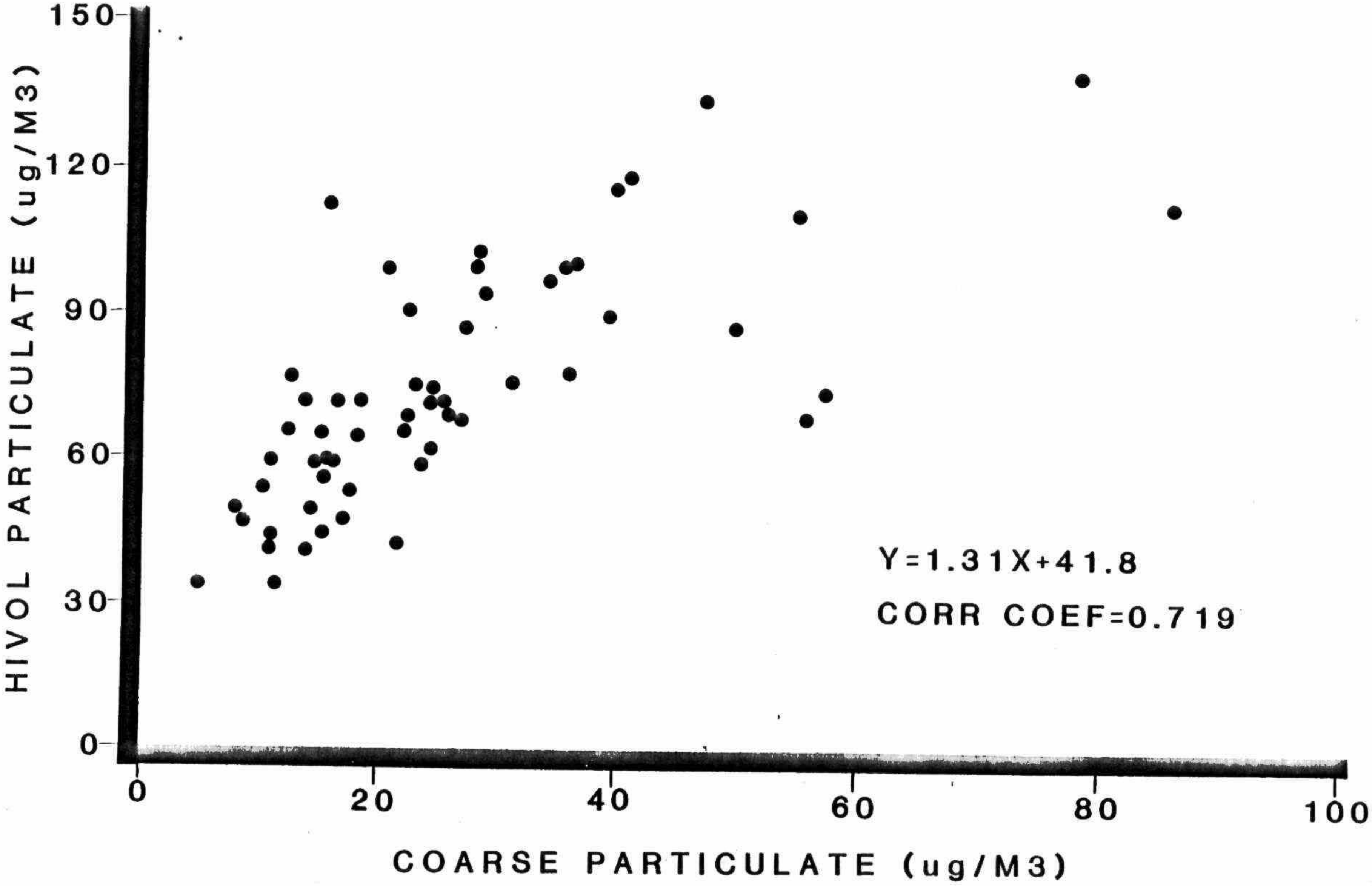


Fig. 12

HIVOL VS FINE DICHOTOMOUS CONCENTRATIONS

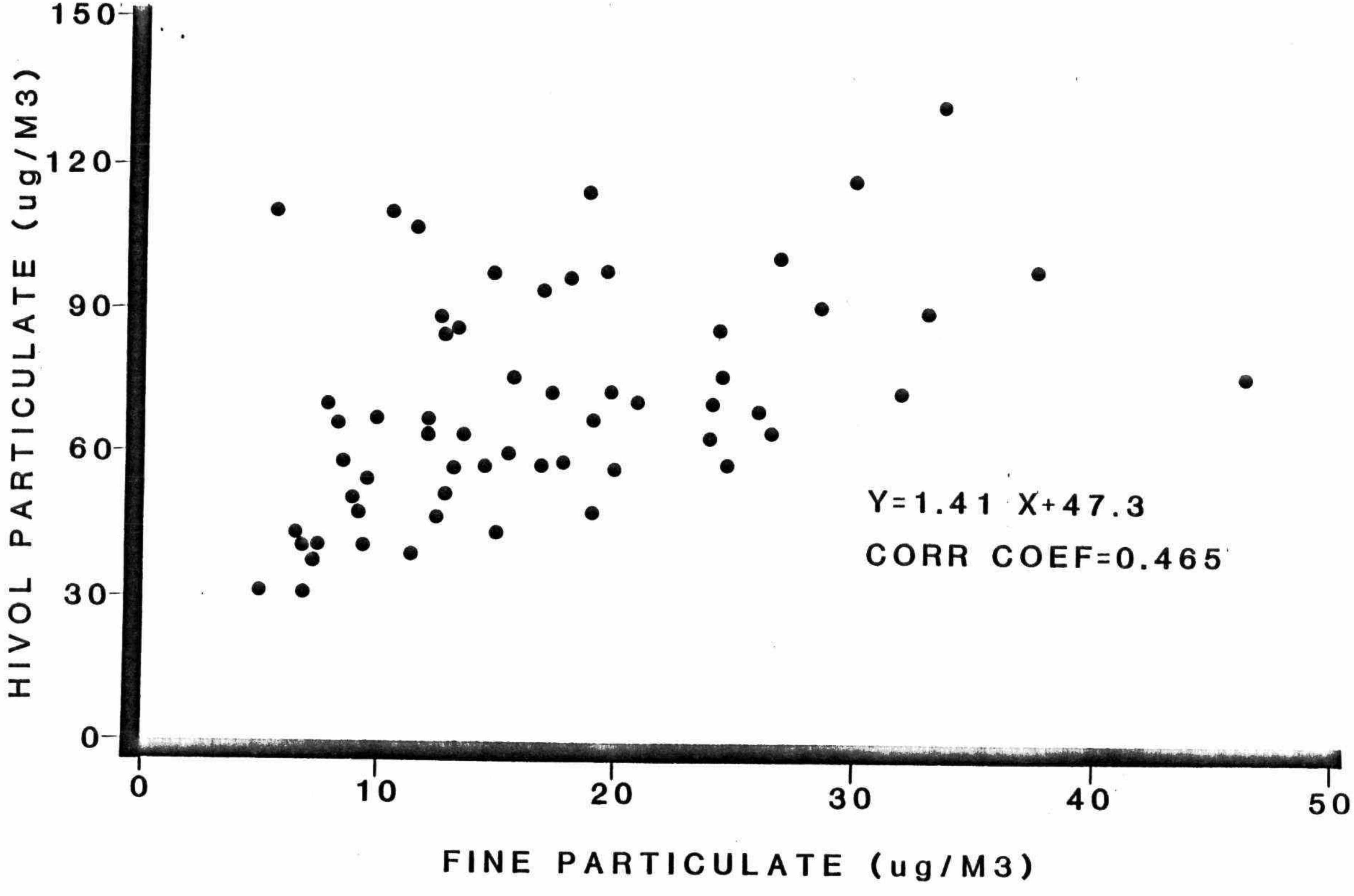


Fig. 13

SIZE SELECTIVE INLET HIVOL VS
TOTAL DICHOTOMOUS CONCENTRATIONS

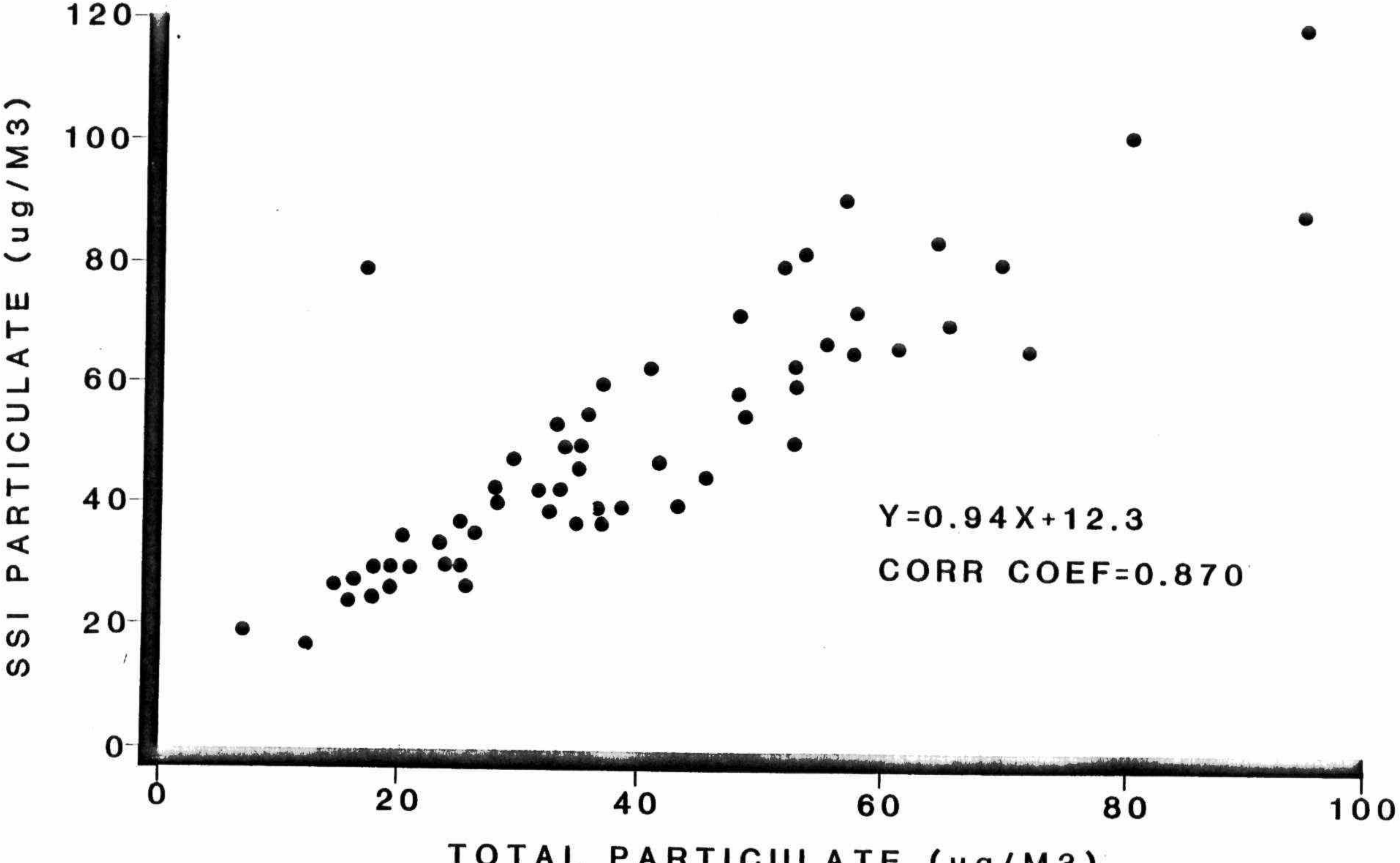


Fig. 14

SIZE SELECTIVE INLET HIVOL VS COARSE DICHOTOMOUS CONCENTRATIONS

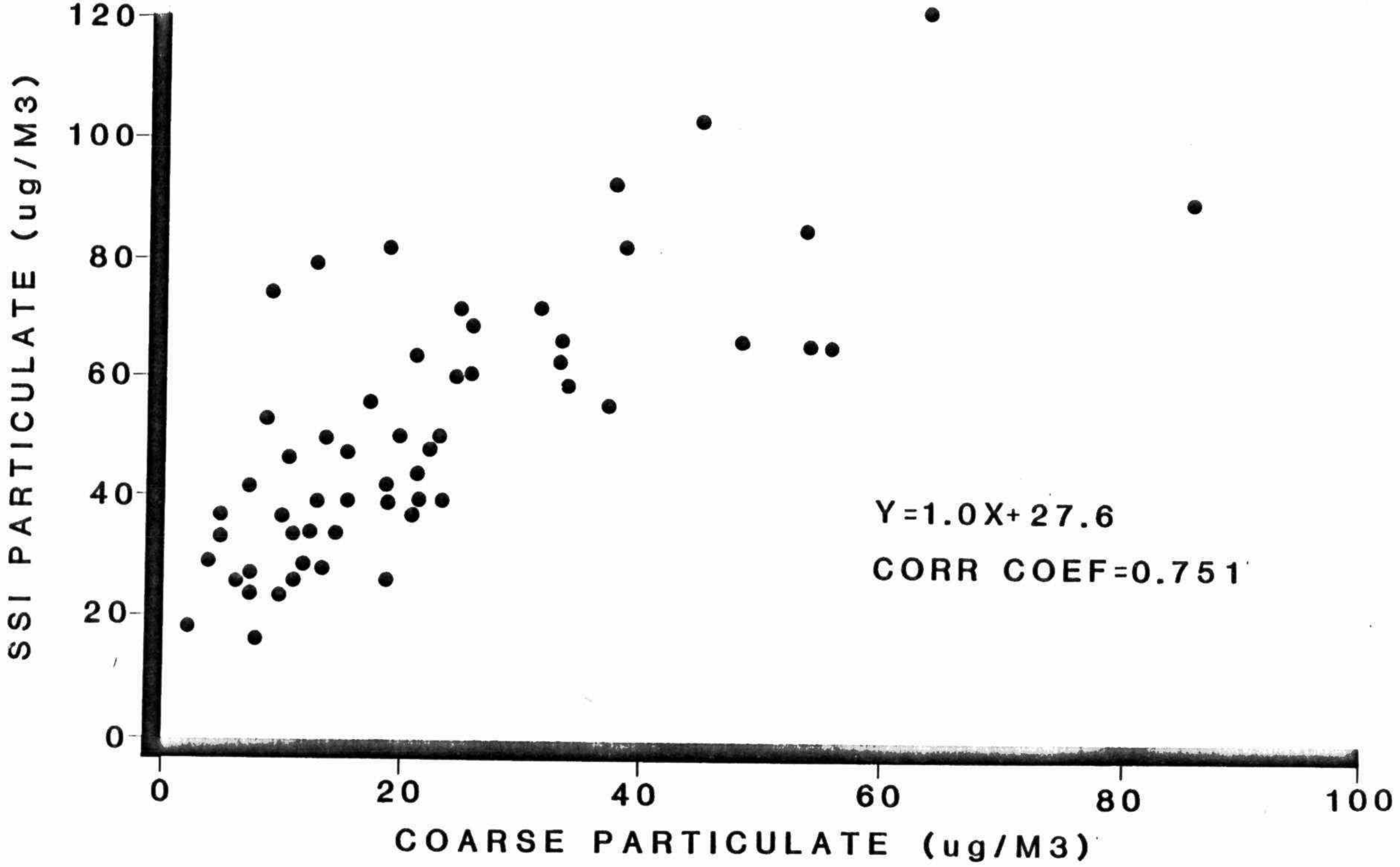


Fig. 15

SIZE SELECTIVE INLET HIVOL VS FINE DICHOTOMOUS CONCENTRATIONS

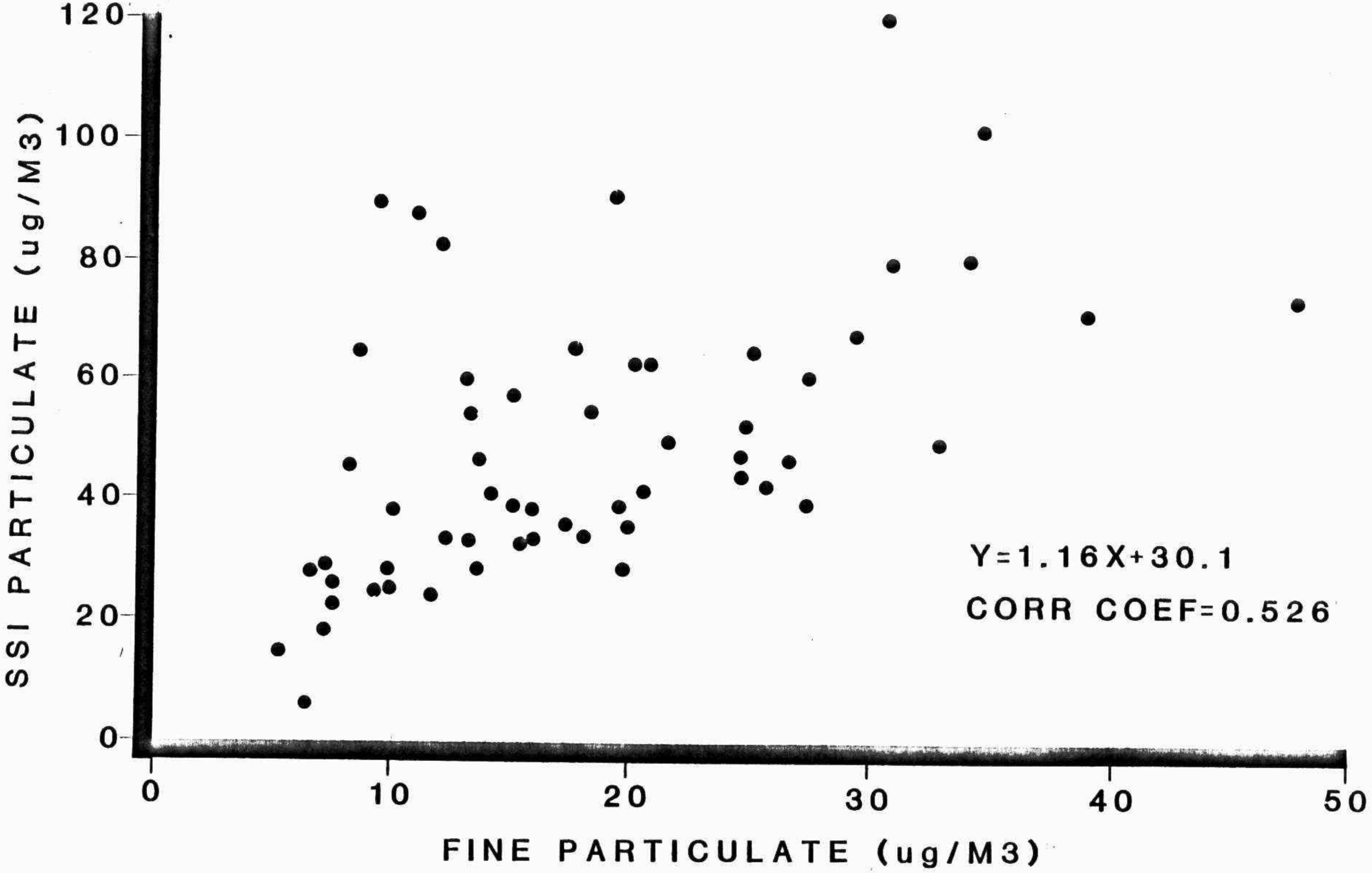


Fig. 16

TOTAL VS COARSE DICHOTOMOUS CONCENTRATIONS

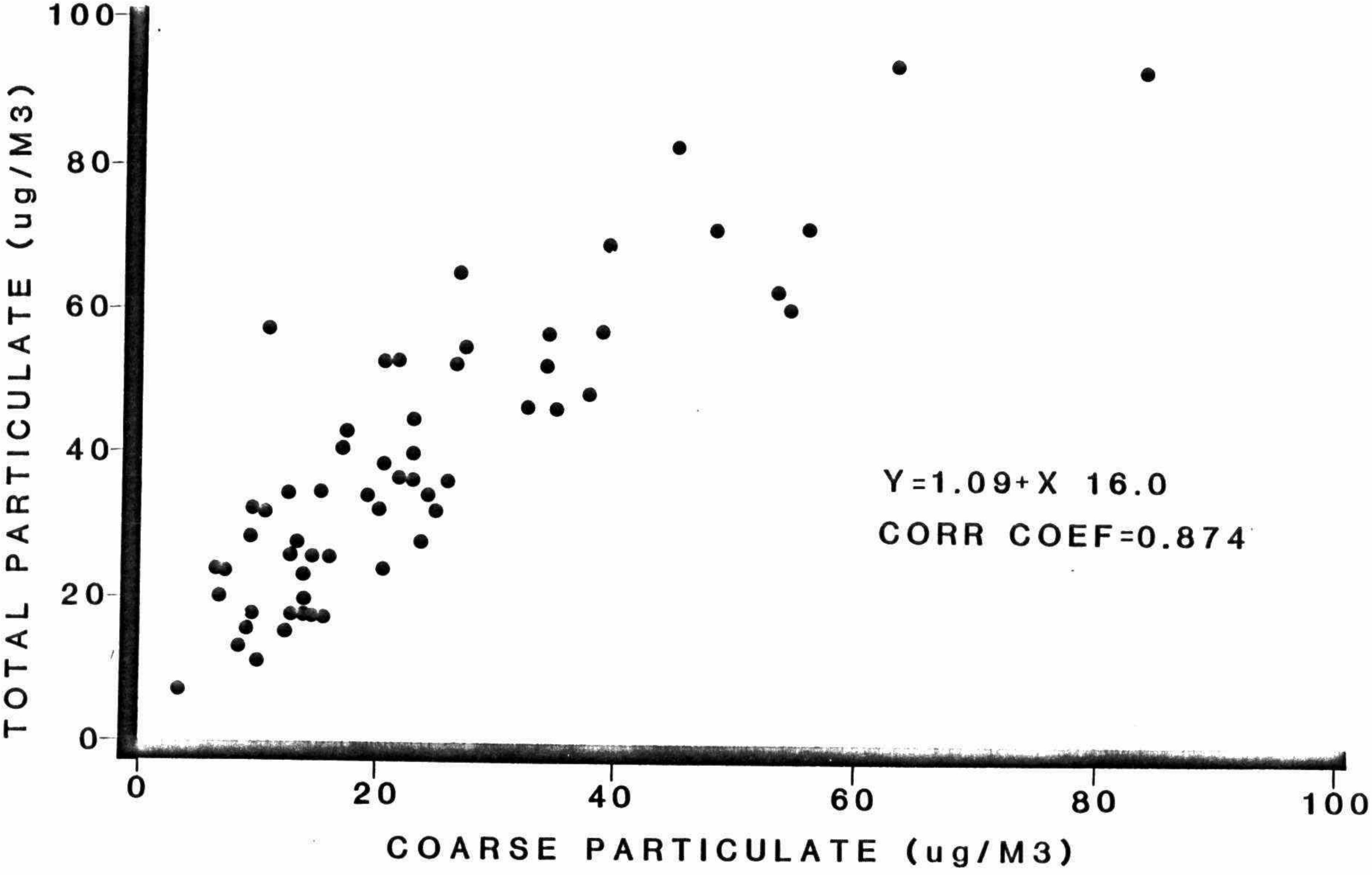


Fig. 17

TOTAL VS FINE DICHOTOMOUS CONCENTRATIONS

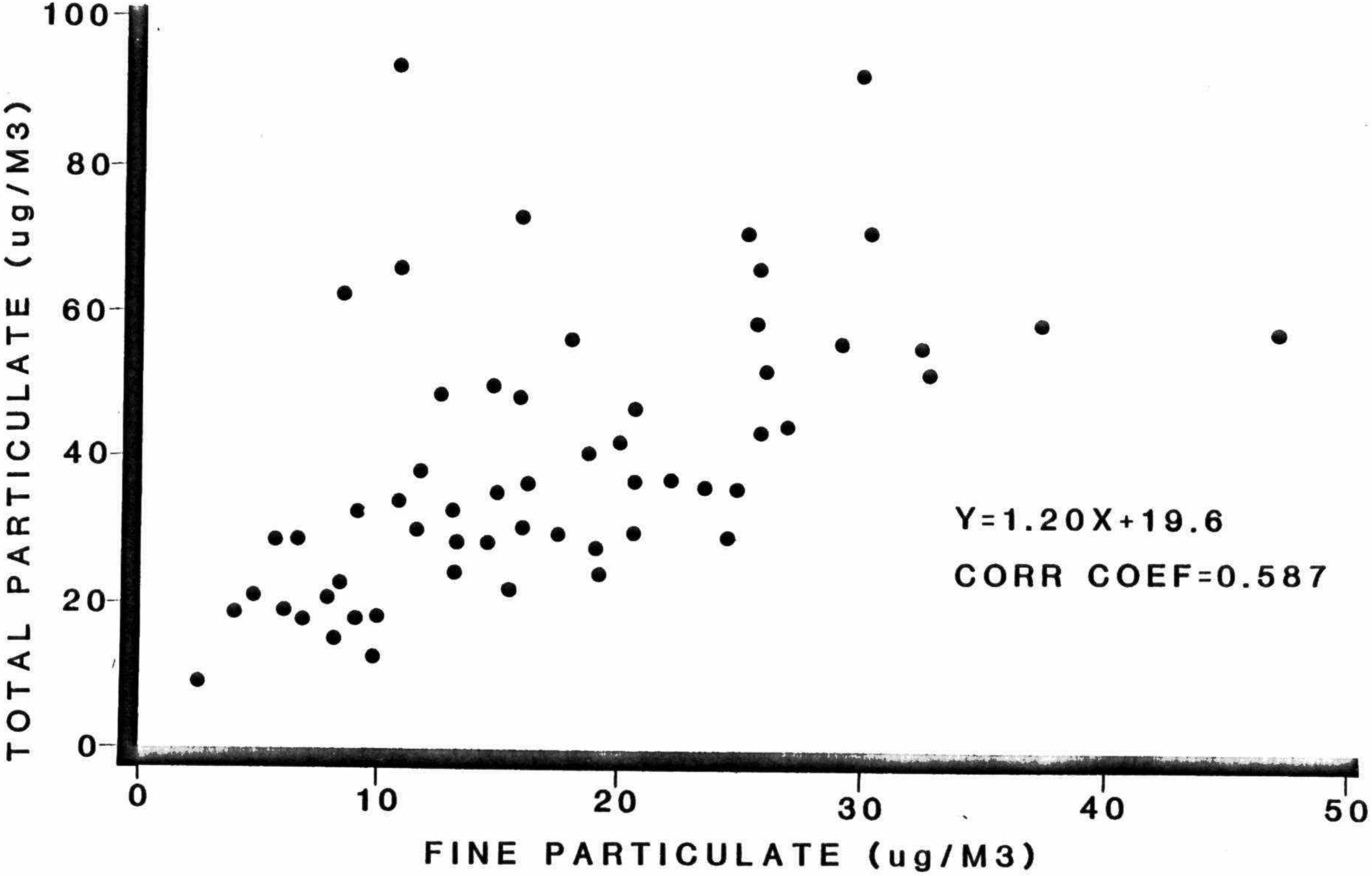


Fig. 18

FINE VS COARSE DICHOTOMOUS CONCENTRATIONS

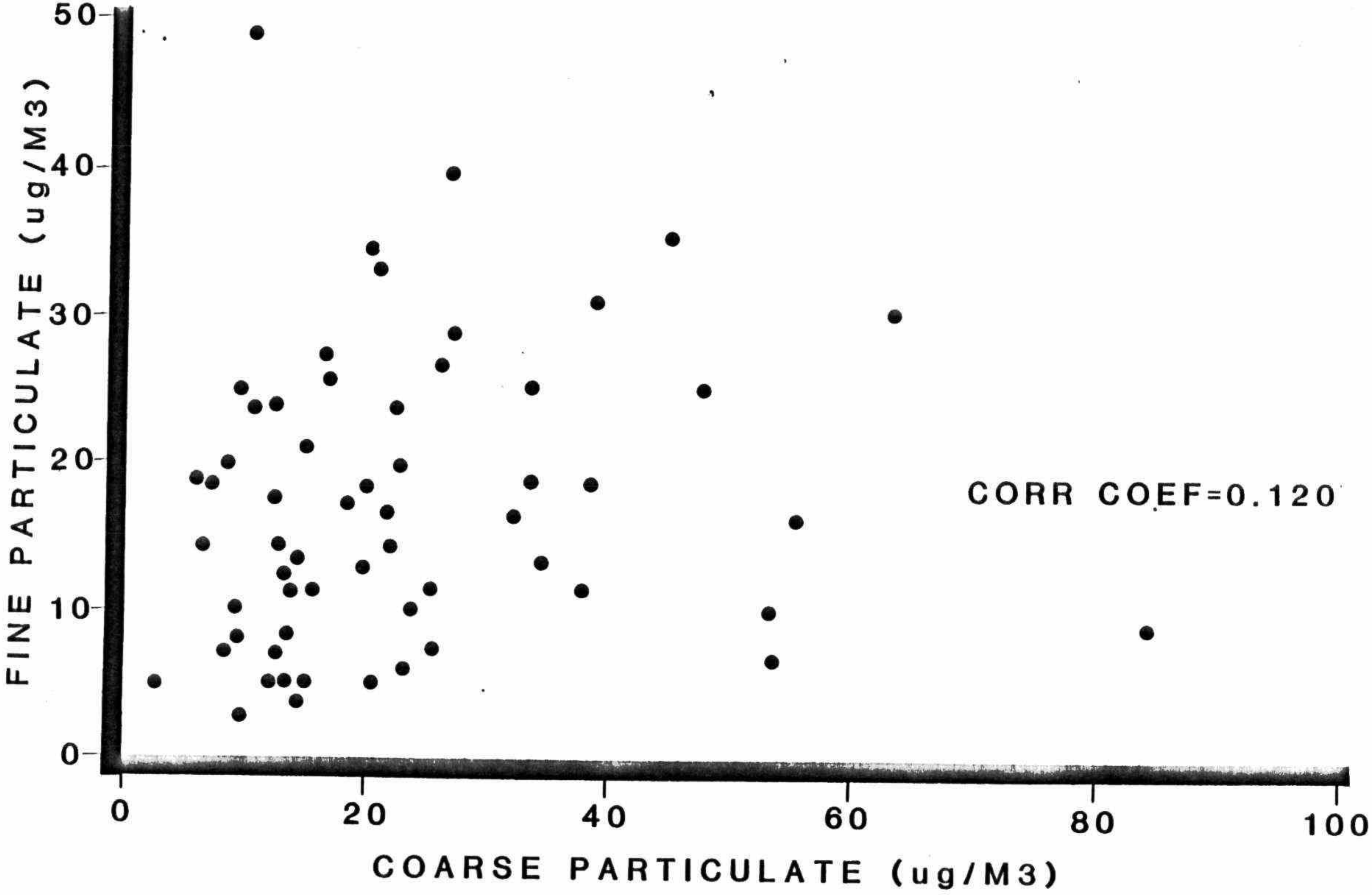


Fig. 19

SIERRA AUTOMATIC VS ANDERSEN FINE CONCENTRATIONS

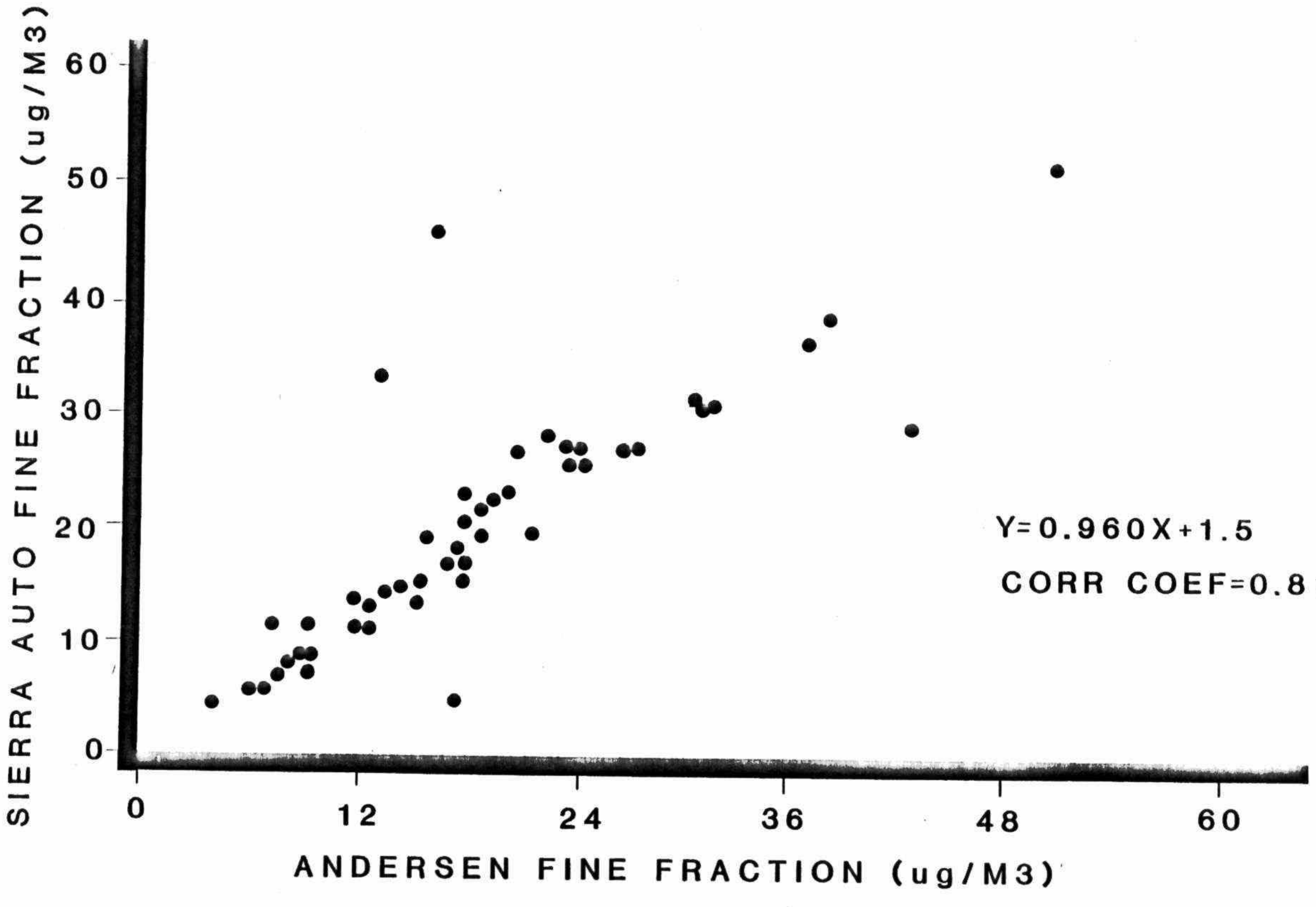


Fig. 20

SIERRA MANUAL VS ANDERSEN FINE CONCENTRATIONS

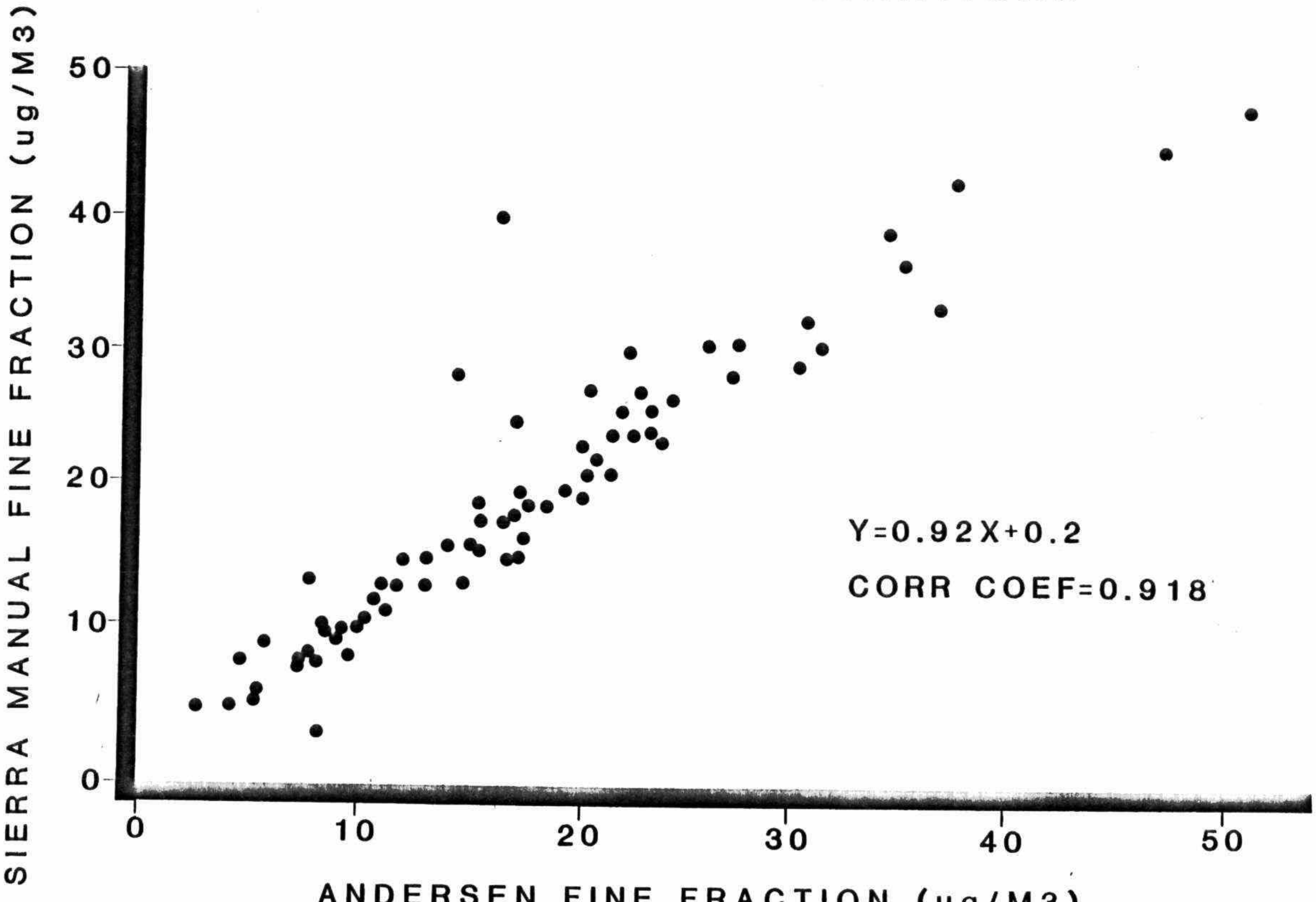


Fig. 21

SIERRA MANUAL VS SIERRA AUTOMATIC FINE CONCENTRATIONS

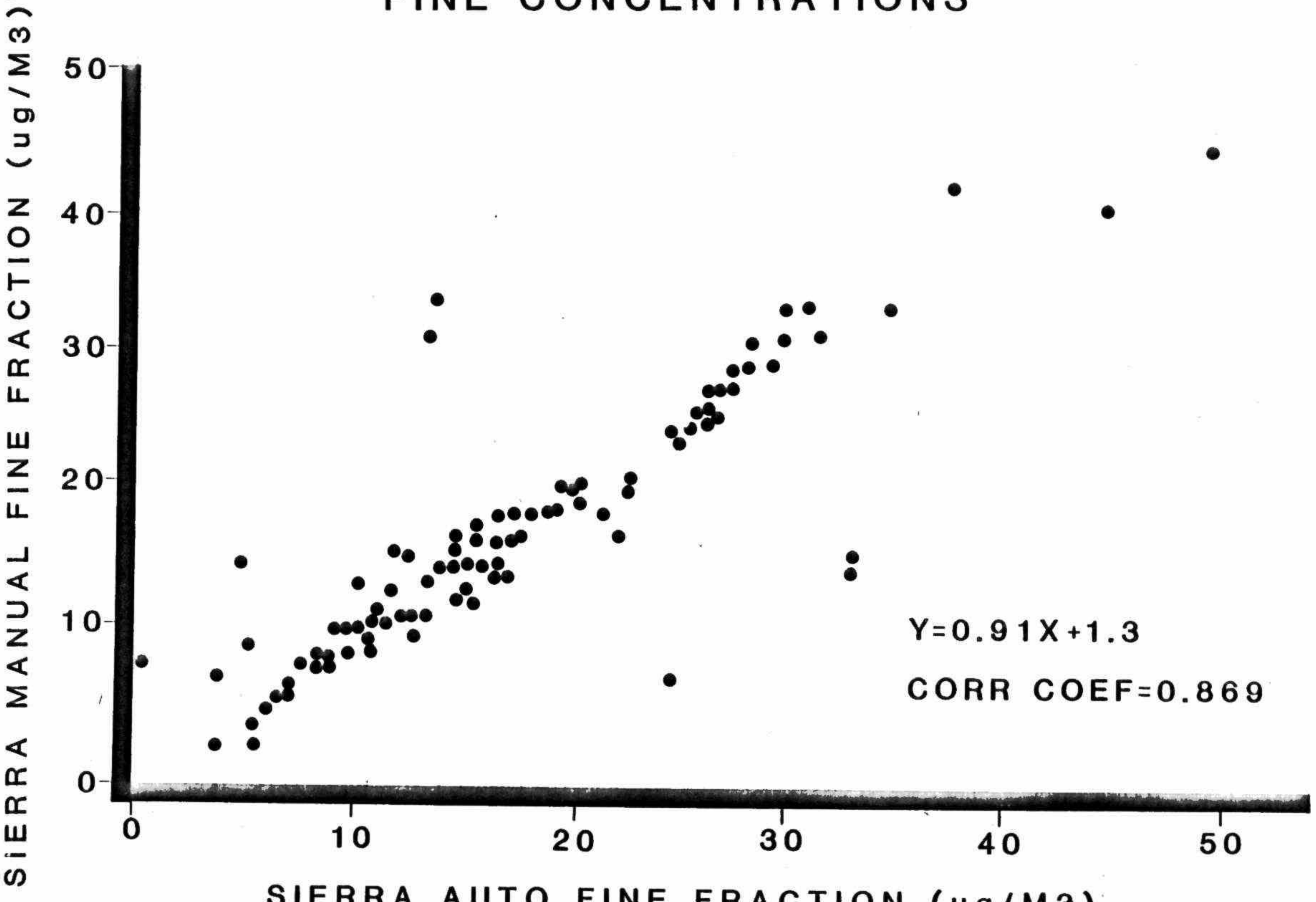


Fig. 22

SIERRA MANUAL VS ANDERSEN COARSE CONCENTRATIONS

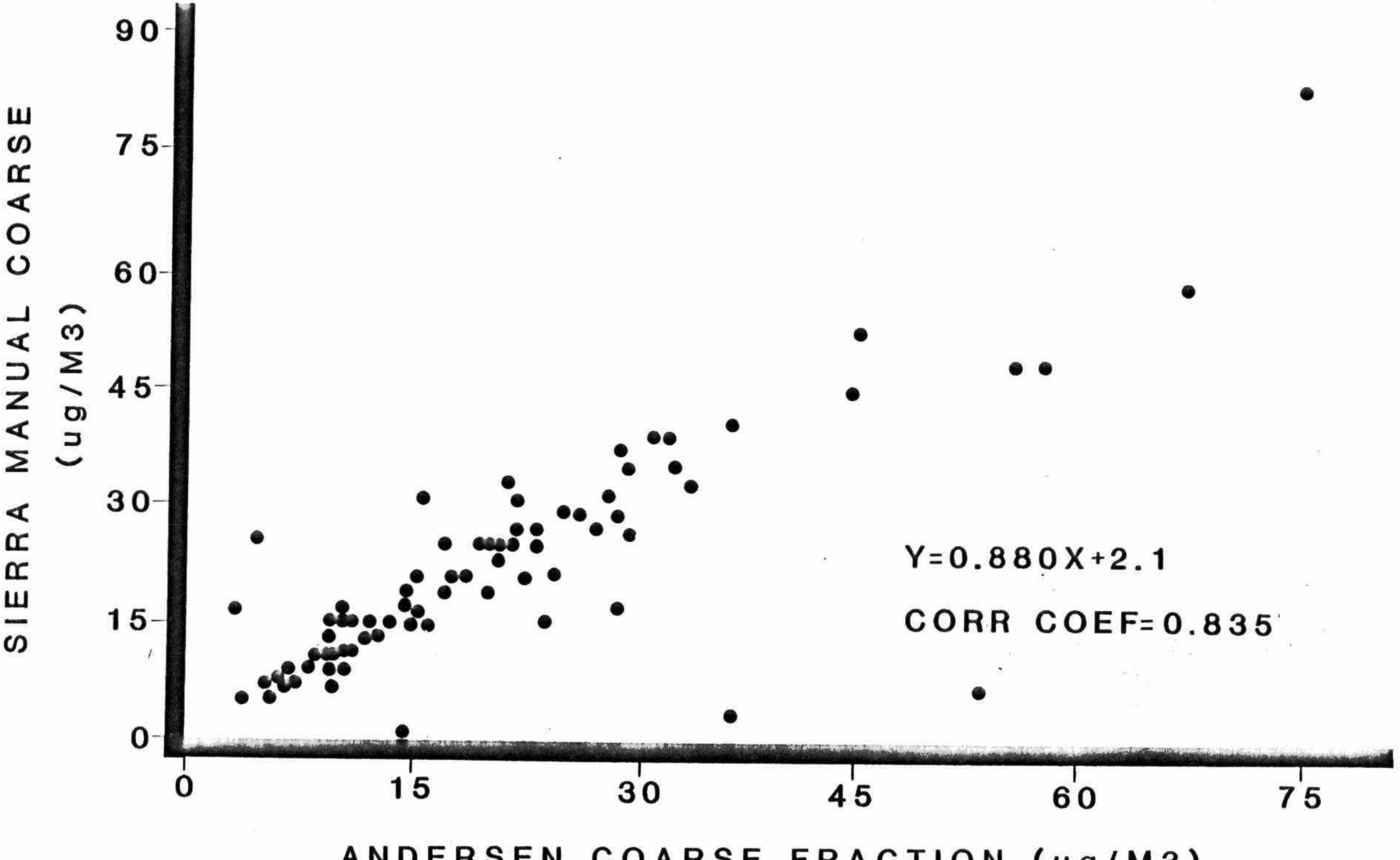
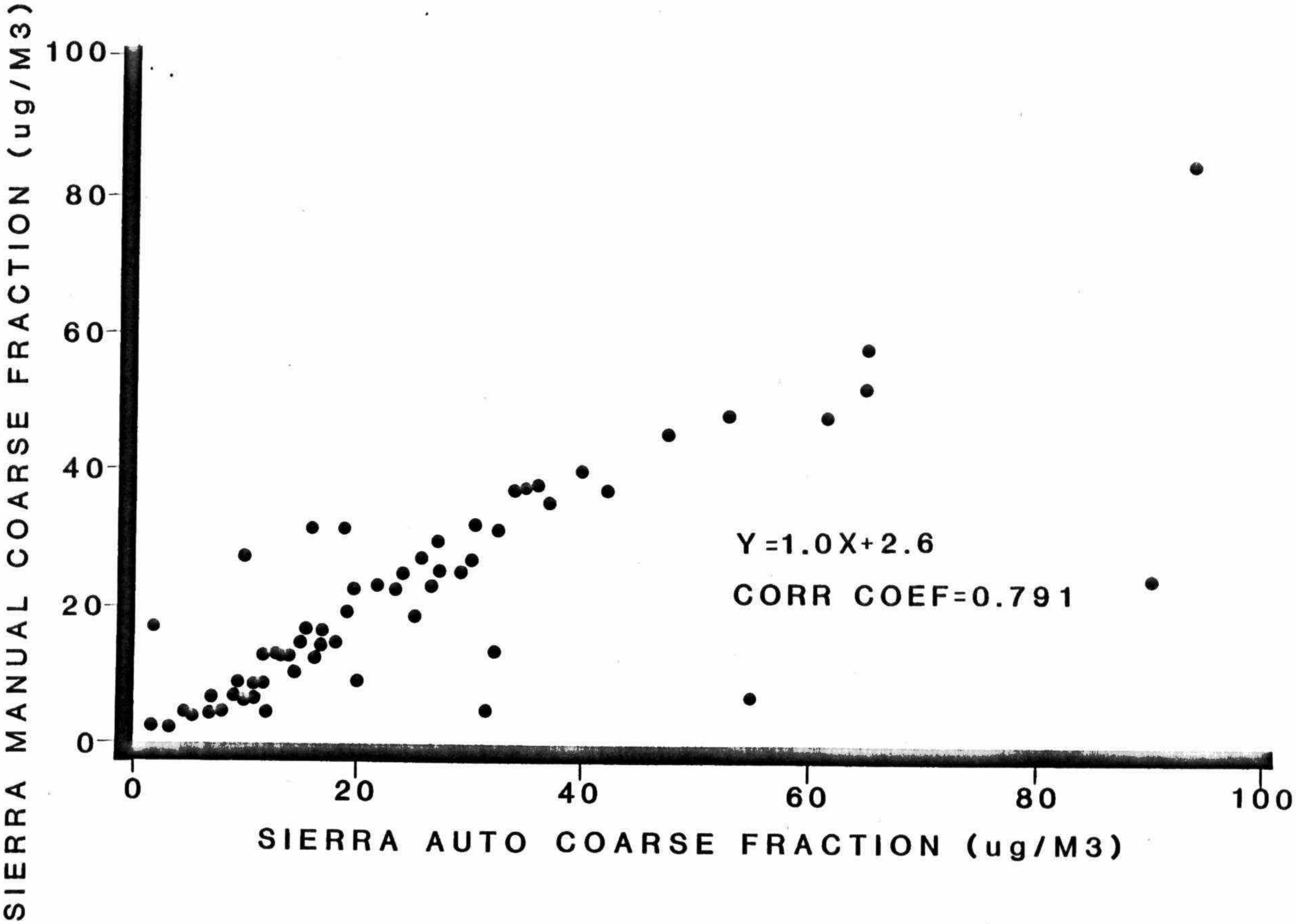


Fig. 23



SIERRA MANUAL VS SIERRA AUTOMATIC COARSE CONCENTRATIONS

Fig. 24

SIERRA AUTOMATIC VS ANDERSEN COARSE CONCENTRATIONS

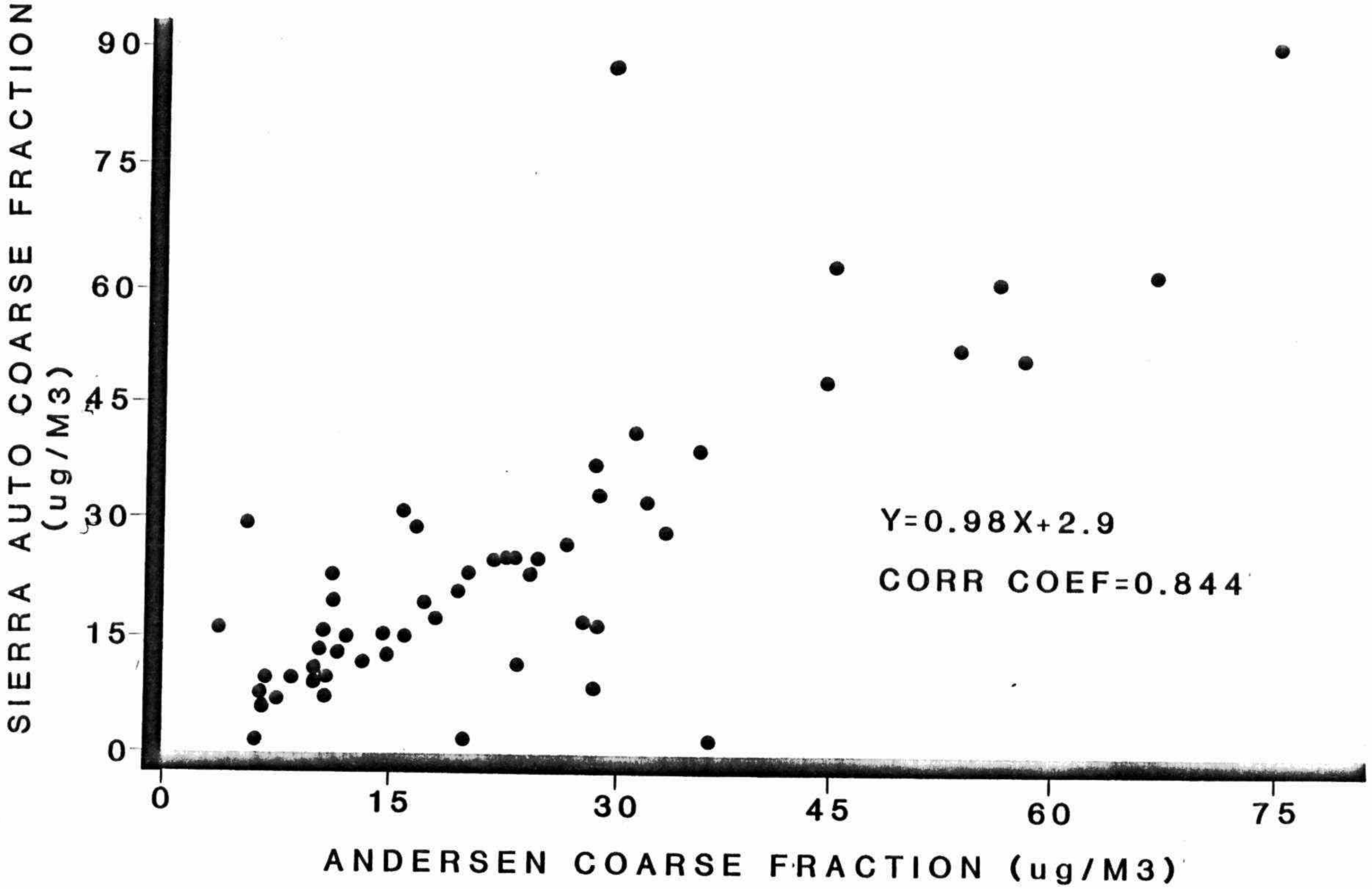
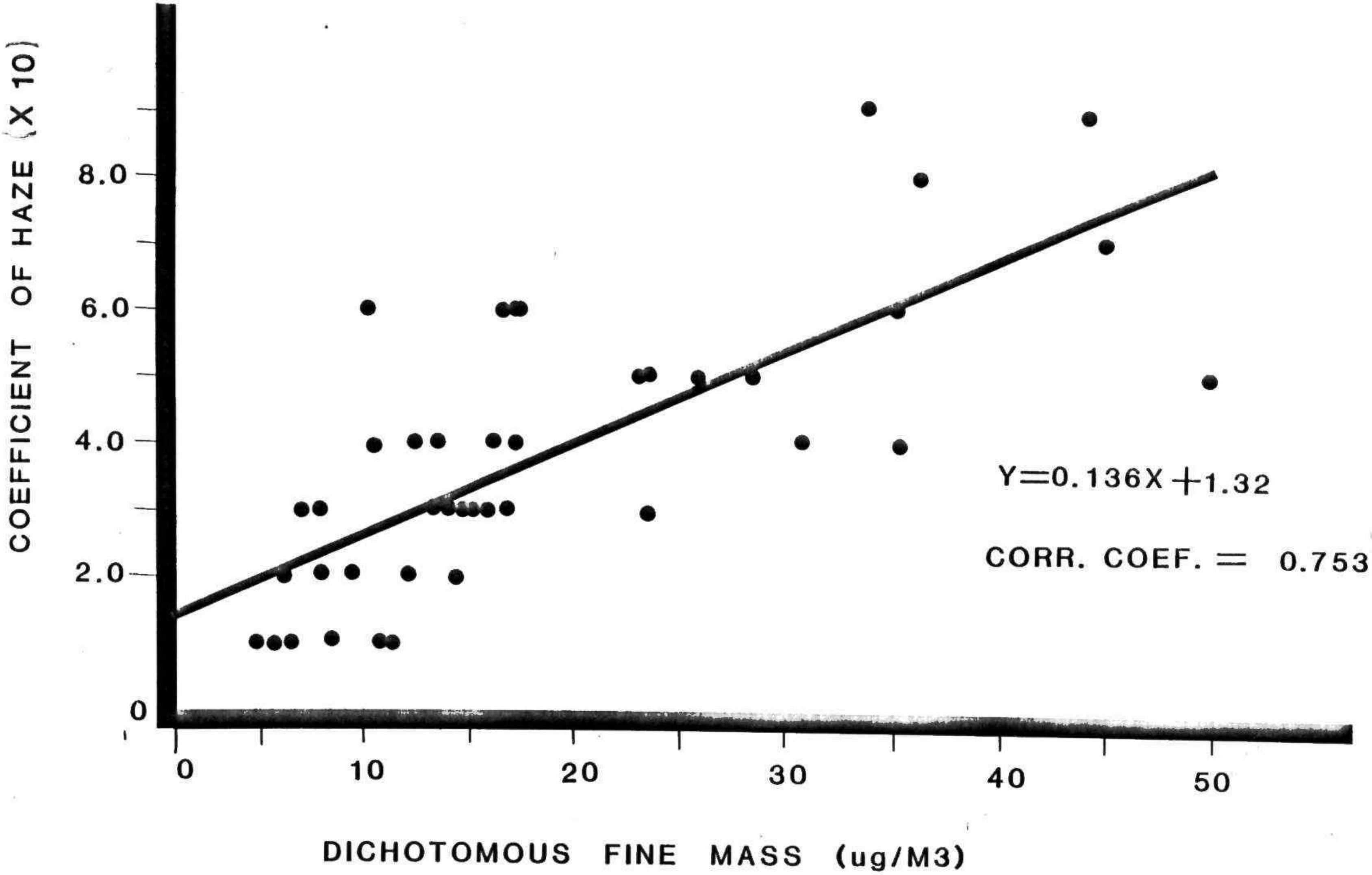


Fig. 25

COEFFICIENT OF HAZE SAMPLER VS DICHOTOMOUS FINE MASS



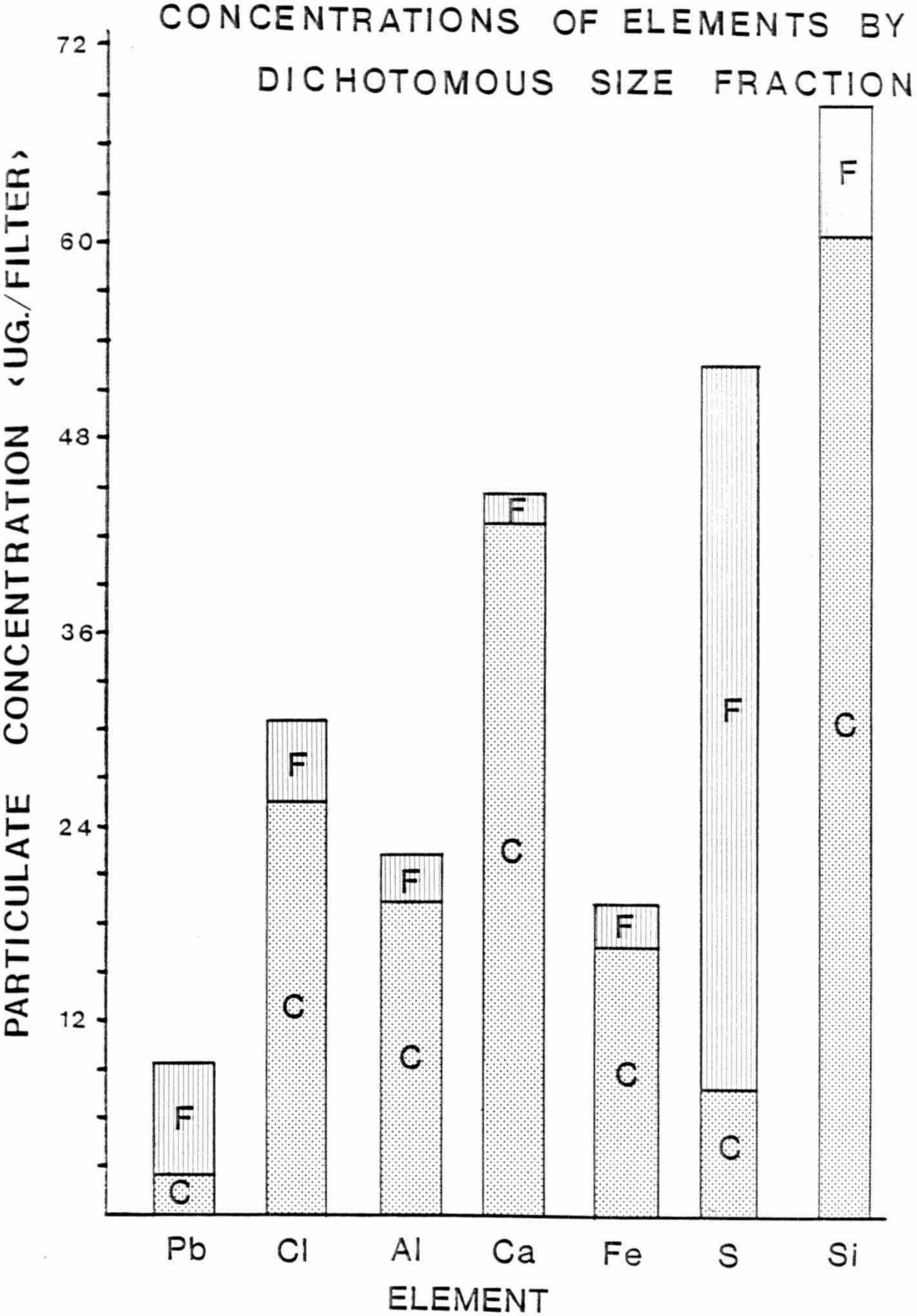
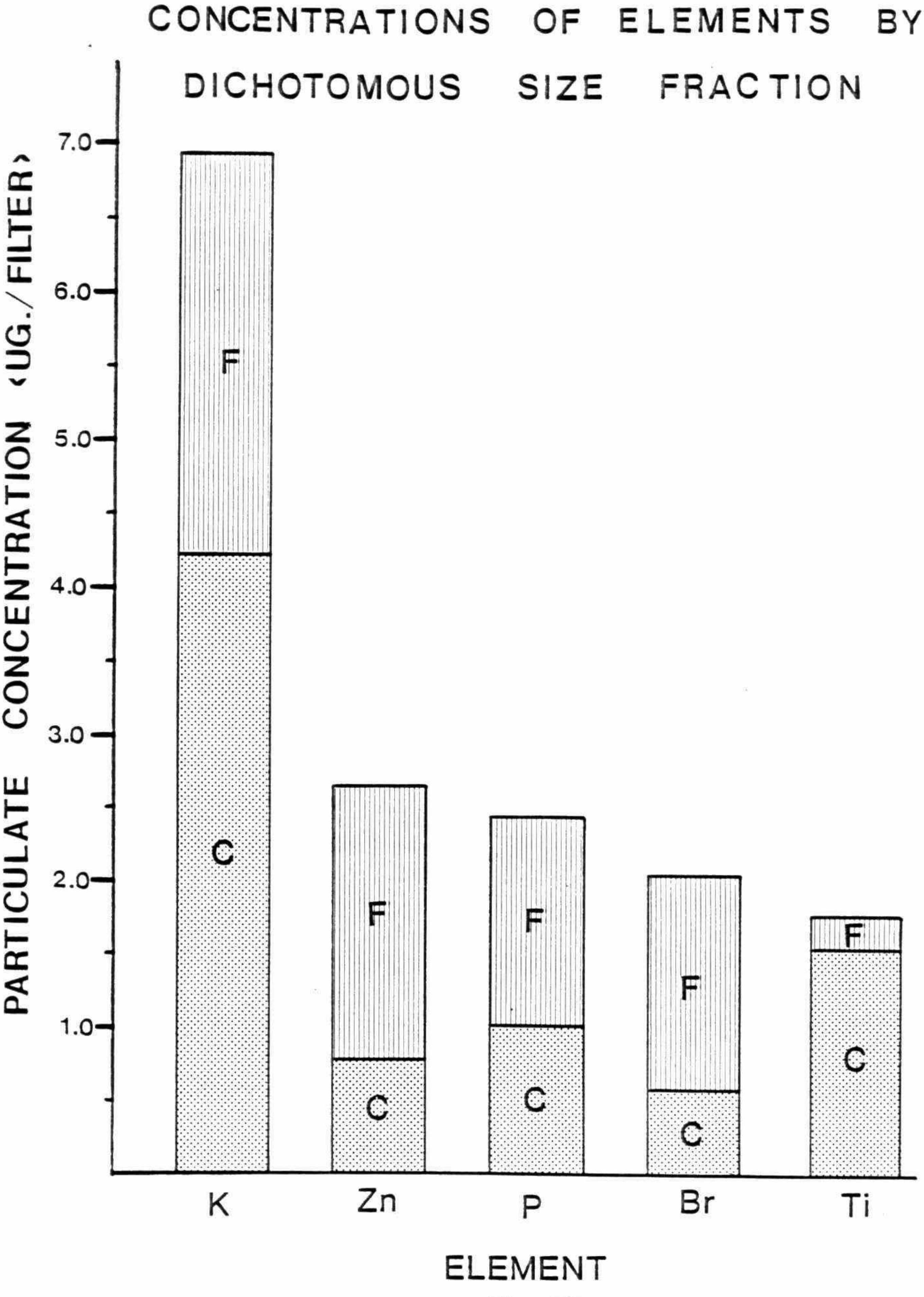

CONCENTRATIONS OF ELEMENTS BY DICHOTOMOUS SIZE FRACTION
PARTICULATE CONCENTRATION <UG./FILTER>
72
60
48
36
24
12
F
C
Pb
Cl
Al
Ca
Fe
S
Si
ELEMENT

Fig. 26



CONCENTRATIONS OF ELEMENTS BY DICHOTOMOUS SIZE FRACTION

Fig. 27

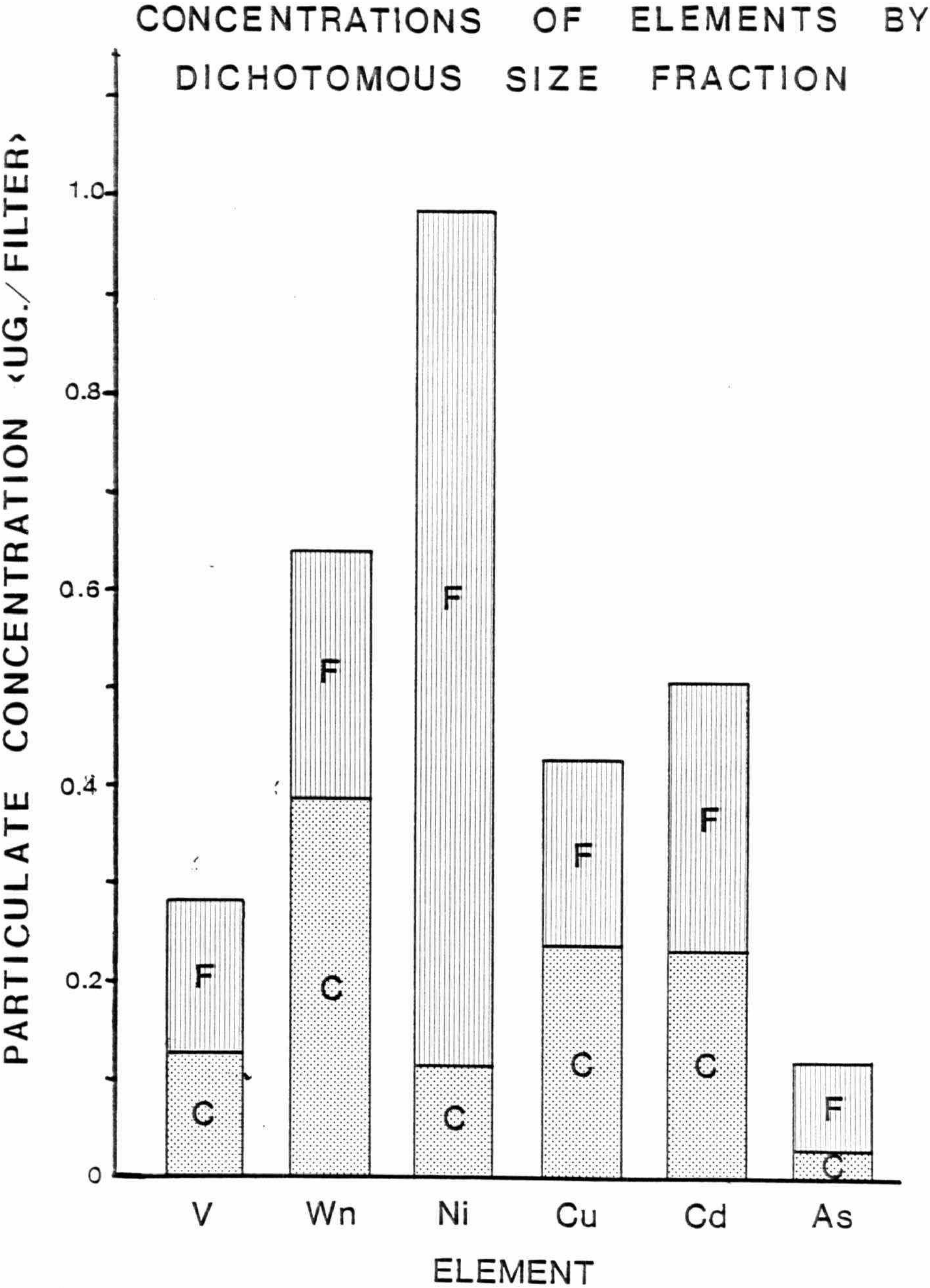

CONCENTRATIONS OF ELEMENTS BY DICHOTOMOUS SIZE FRACTION
PARTICULATE CONCENTRATION ‹UG./FILTER›
1.0
0.8
0.6
0.4
0.2
0
F
C
V
Wn
Ni
Cu
Cd
As
ELEMENT

Fig. 28

Fig. 29

VARIATIONS IN PARTICULATE LEVELS DURING A POLLUTION INVERSION EPISODE IN DOWNTOWN TORONTO

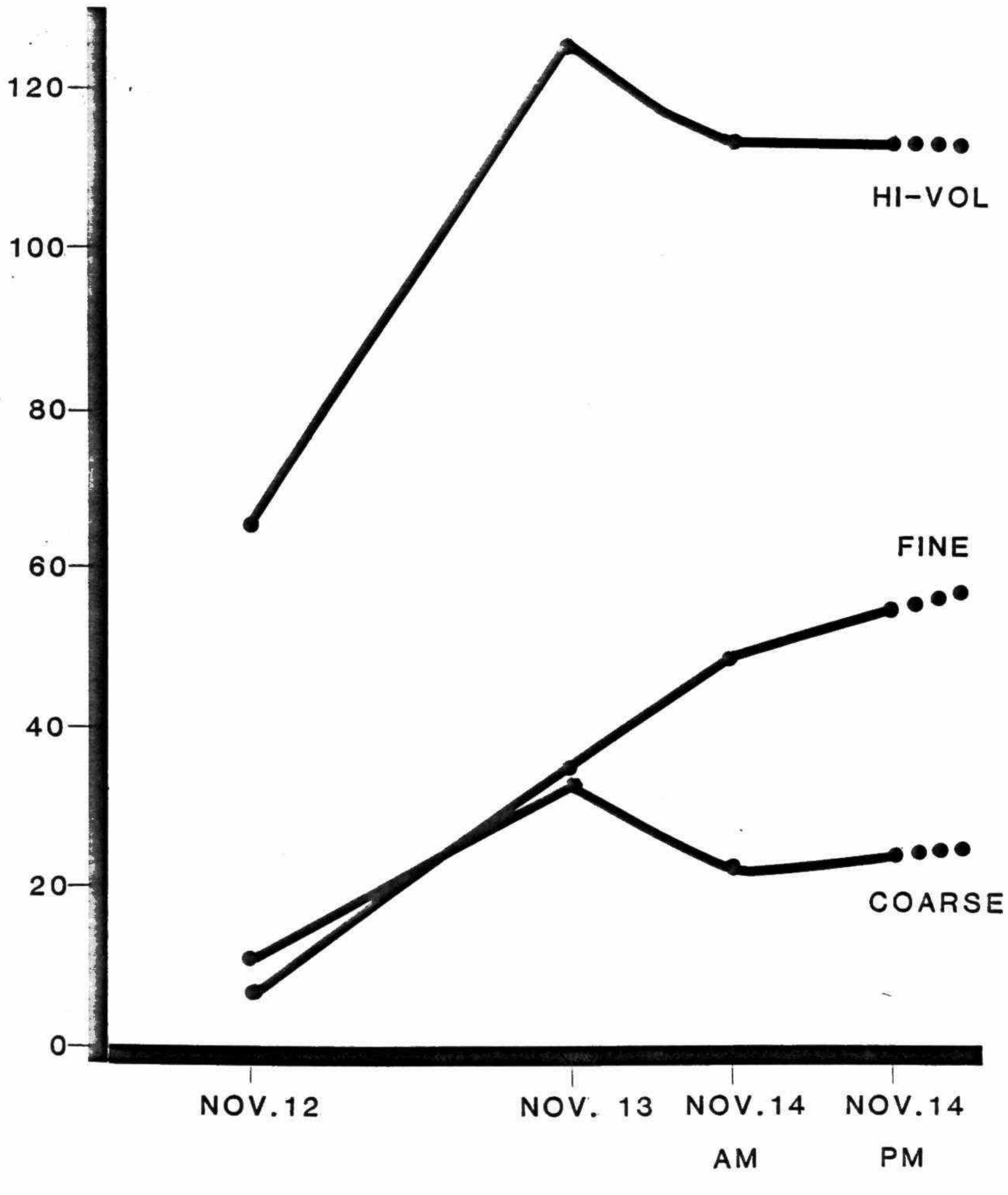


TABLE 1.0

DICHOTOMOUS SAMPLING NETWORK DATA (ug/m^3)*

Date	Sierra Manual (Coarse)	Sierra Manual (Fine)	Sierra Automatic (Coarse)	Sierra Automatic (Fine)	Andersen (Coarse)	Andersen (Fine)	Average of Fine	Average of Coarse	Total (Fine & Coarse)	HiVol	Size Selective Inlet
18SEP1980	11.7	6.3	.	.	.	.	.	.	.	46	.
24SEP1980	12.7	1.4	.	.	.	.	.	.	.	44	.
30SEP1980	28.7	32.8	.	.	.	.	.	.	.	108	.
04OCT1980	4.6	7.2	.	.	.	.	.	.	.	.	.
06OCT1980	13.1	11.6	.	.	.	.	.	.	.	50	.
09OCT1980	10.3	4.2	.	.	.	.	.	.	.	40	.
12OCT1980	2.6	4.8	.	.	.	.	.	.	.	20	.
15OCT1980	12.4	9.4	.	.	.	.	.	.	.	55	.
18OCT1980	9.6	6.1	.	.	.	.	.	.	.	36	.
21OCT1980	6.4	9.2	.	.	.	.	.	.	.	35	.
24OCT1980	16.4	6.8	.	.	.	.	.	.	.	55	.
27OCT1980	8.8	9.2	.	.	.	.	.	.	.	37	.
30OCT1980	14.6	13.3	.	.	.	.	.	.	.	58	.
02NOV1980	4.4	7.9	.	.	.	.	.	.	.	30	.
05NOV1980	5.7	3.8	.	.	.	.	.	.	.	26	13
08NOV1980	4.9	6.0	.	.	.	.	.	.	.	26	15
11NOV1980	13.2	4.2	.	.	.	.	.	.	.	36	23
14NOV1980	6.3	15.2	.	.	.	.	.	.	.	41	33
17NOV1980	7.9	15.0	.	.	.	.	.	.	.	57	41
20NOV1980	16.6	41.4	.	.	.	.	.	.	.	79	67
23NOV1980	11.2	23.1	.	.	.	.	.	.	.	53	46

* . denotes missing data

TABLE 1.1

DICHOTOMOUS SAMPLING NETWORK DATA (ug/m^3) - Continued

Date	Sierra Manual (Coarse)	Sierra Manual (Fine)	Sierra Automatic (Coarse)	Sierra Automatic (Fine)	Andersen (Coarse)	Andersen (Fine)	Average of Fine	Average of Coarse	Total (Fine & Coarse)	HiVol	Size Selective Inlet
26NOV1980	16.7	20.0	.	.	.	.	.	.	.	64	49
29NOV1980	5.5	12.0	.	.	.	.	.	.	.	30	24
02DEC1980	57.9	75.9	.	.	.	.	.	.	.	54	41
05DEC1980	.	.	.	.	.	.	.	.	.	86	60
08DEC1980	.	.	.	.	.	.	.	.	.	.	49
11DEC1980	28.3	9.2	29.9	9.4	.	.	.	.	.	81	49
17DEC1980	25.8	19.0	29.4	19.4	.	.	.	.	.	89	59
23DEC1980	25.7	40.4	29.2	44.9	4.9	16.1	33.8	19.9	53.7	91	81
26DEC1980	6.5	18.4	7.1	21.1	6.7	18.4	19.3	6.7	26.1	44	38
29DEC1980	5.4	31.2	5.6	31.8	.	.	.	.	.	50	47
01JAN1981	6.3	14.8	7.7	14.7	5.8	15.0	14.8	6.6	21.4	44	35
04JAN1981	7.0	10.7	7.0	7.9	.	.	.	.	.	35	27
07JAN1981	7.6	10.8	9.8	10.9	9.4	11.1	10.9	8.9	19.9	35	26
10JAN1981	9.2	12.8	10.4	14.8	.	.	.	.	.	43	32
13JAN1981	10.5	24.0	10.9	25.2	9.6	23.9	24.4	10.3	34.7	64	52
16JAN1981	0.0	22.4	3.9	25.1	.	.	.	.	.	44	41
19JAN1981	10.7	44.4	10.3	49.8	9.5	51.2	48.5	10.2	58.6	78	73
22JAN1981	5.5	26.0	4.7	26.1	.	.	.	.	.	43	32
25JAN1981	28.4	14.3	9.4	33.0	28.6	12.7	20.0	22.1	42.1	73	63
28JAN1981	6.1	34.0	31.6	14.2	.	.	.	.	.	86	51
02MAR1981	.	.	.	.	.		.	.	.	55	30
05MAR1981	15.2	19.7	.	.	15.2	20.0	.	.	.	65	52

TABLE 1.2

DICHOTOMOUS SAMPLING NETWORK DATA ($\mu g/m^3$) - Continued

Date	Sierra Manual (Coarse)	Sierra Manual (Fine)	Sierra Automatic (Coarse)	Sierra Automatic (Fine)	Andersen (Coarse)	Andersen (Fine)	Average of Fine	Average of Coarse	Total (Fine & Coarse)	HiVol	Size Selective Inlet
08MAR1981	13.7	7.8	12.1	6.7	9.3	4.9	6.4	11.7	18.2	35	26
11MAR1981	5.7	9.2	12.0	10.9	9.1	6.7	8.9	8.9	17.9	39	28
14MAR1981	13.3	5.7	15.3	6.7	11.6	5.9	6.1	13.4	19.5	40	31
17MAR1981	3.3	2.6	2.7	3.7	36.9	8.1	4.8	14.3	19.1	112	78
20MAR1981	13.1	12.7	16.1	15.2	14.6	15.1	14.3	14.6	28.9	56	41
26MAR1981	43.2	33.0	47.0	35.0	44.6	36.9	34.9	44.9	79.9	138	99
29MAR1981	25.8	28.7	27.3	29.1	26.9	30.3	29.4	26.7	56.1	93	67
01APR1981	6.8	16.8	54.9	21.9	53.7	17.3	18.7	38.5	57.1	117	89
04APR1981	25.6	23.6	89.8	26.2	29.4	24.2	24.7	48.3	72.9	88	66
07APR1981	32.0	16.8	29.9	15.6	33.9	17.7	16.7	31.9	48.6	98	69
10APR1981	48.8	13.1	52.7	13.1	58.1	7.5	11.2	53.2	64.4	110	82
13APR1981	13.7	7.6	31.6	3.7	15.6	8.0	6.4	20.3	26.7	40	27
16APR1981	30.6	15.4	18.5	4.9	27.9	17.0	12.4	25.7	38.1	85	60
22APR1981	20.9	7.2	24.9	7.1	24.3	7.0	7.1	23.4	30.5	70	48
25APR1981	4.7	4.7	.	.	2.8	4.7	.	.	.	26	19
28APR1981	25.4	10.4	23.9	12.9	22.1	10.9	11.4	23.8	35.2	68	49
01MAY1981	10.5	5.1	24.3	6.1	10.8	5.6	5.6	15.2	20.8	42	29
04MAY1981	57.1	30.1	64.5	29.4	67.8	31.4	30.3	63.1	93.4	181	118
27JUN1981	17.4	5.9	15.2	7.0	.	.	.	.	.	58	33
03JUL1981	19.4	18.7	19.0	18.0	17.7	17.2	17.9	18.7	36.7	100	55
09JUL1981	33.9	26.8	36.8	26.7	29.5	20.4	24.6	33.4	58.0	75	64

TABLE 1.3

DICHOTOMOUS SAMPLING NETWORK DATA (ug/m^3) - Continued

Date	Sierra Manual (Coarse)	Sierra Manual (Fine)	Sierra Automatic (Coarse)	Sierra Automatic (Fine)	Andersen (Coarse)	Andersen (Fine)	Average of Fine	Average of Coarse	Total (Fine & Coarse)	HiVol	Size Selective Inlet
15JUL1981	52.2	8.2	64.7	8.0	45.0	7.0	7.7	53.9	61.7	68	65
21JUL1981	19.8	23.6	25.0	25.6	22.2	23.7	24.3	22.4	46.6	69	45
27JUL1981	18.5	11.7	1.8	12.3	19.8	11.0	11.7	13.4	25.0	63	36
02AUG1981	21.2	53.7	.	.	20.3	53.8	.	.	.	105	68
08AUG1981	12.6	26.7	.	.	12.6	24.6	.	.	.	63	44
14AUG1981	19.0	17.6	.	.	18.4	17.0	.	.	.	60	38
20AUG1981	31.7	17.7	.	.	21.4	15.3	.	.	.	84	50
26AUG1981	24.5	22.8	.	.	20.4	19.8	.	.	.	80	51
01SEP1981	25.2	36.0	.	.	23.3	35.2	.	.	.	94	70
07SEP1981	13.4	21.3	.		11.9	20.9	.	.	.	56	36
13SEP1981	28.3	41.7	25.2	37.9	24.7	37.8	39.1	26.1	65.2	100	69
19SEP1981	23.5	15.1	23.5	15.2	20.2	15.0	15.1	22.4	37.5	61	40
25SEP1981	34.9	30.7	.	.	32.4	27.8	.	.	.	96	65
01OCT1981	23.3	18.0	21.9	15.9	19.3	16.3	16.7	21.5	38.2	55	37
07OCT1981	10.2	3.9	8.9	5.4	10.3	3.0	4.1	9.8	13.9	31	18
13OCT1981	15.7	21.4	14.9	22.2	14.3	20.0	21.2	14.9	36.2	69	49
19OCT1981	9.4	4.2	.	.	8.3	4.2	.	.	.	39	15
25OCT1981	11.7	18.0	.	.	8.9	15.3	.			46	33
31OCT1981	17.4	24.7	.	.	16.9	22.8	.		.	72	47
06NOV1981	9.3	10.1	.	.	8.9	9.6	.	.	.	38	23
12NOV1981	13.8	9.2	13.7	7.8	9.9	8.3	8.4	12.5	20.9	45	28

TABLE 1.4

DICHOTOMOUS SAMPLING NETWORK DATA (ug/m^3) - Continued

Date	Sierra Manual (Coarse)	Sierra Manual (Fine)	Sierra Automatic (Coarse)	Sierra Automatic (Fine)	Andersen (Coarse)	Andersen (Fine)	Average of Fine	Average of Coarse	Total (Fine & Coarse)	HiVol	Size Selective Inlet
18NOV1981	15.2	10.1	16.6	8.2	9.7	8.6	8.9	13.8	22.8	52	29
24NOV1981	15.6	13.3	16.4	11.7	14.6	12.2	12.4	15.5	27.9	50	35
30NOV1981	30.6	31.2	15.6	13.9	15.6	12.6	19.2	20.6	39.8	68	41
06DEC1981	3.9	8.3	1.3	0.3	4.9	9.1	5.9	3.4	9.3	31	21
12DEC1981	9.9	7.3	19.3	24.9	10.5	6.6	12.9	13.2	26.2	55	31
18DEC1981	14.9	27.9	11.6	26.7	24.1	27.4	27.3	16.9	44.2	62	39
24DEC1981	15.9	24.0	16.8	25.4	3.1	23.8	24.4	11.9	36.3	71	47
30DEC1981	16.3	27.3	17.8	27.8	28.5	43.0	32.7	20.9	53.6	72	50
05JAN1982	24.6	10.1	26.5	9.1	23.1	8.2	9.1	24.7	33.9	67	41
11JAN1982	47.7	17.9	61.7	18.3	56.3	15.3	17.2	55.2	72.4	72	64
17JAN1982	23.6	13.4	19.7	13.2	16.6	12.9	13.2	19.9	33.1	64	42
23JAN1982	12.7	16.2	14.2	14.7	10.9	14.2	15.0	12.6	27.7	47	36
29JAN1982	14.0	19.0	.	.	10.6	16.7	.	.	.	56	39
04FEB1982	5.8	12.3	.	.	5.2	12.7	.	.	.	36	28
10FEB1982	.	.	.	.	.	.	.	.	.	45	36
16FEB1982	9.9	27.0	9.2	26.2	8.0	22.8	25.3	9.0	34.4	56	43
22FEB1982	8.3	13.0	.		7.8	12.4	.	.	.	44	31
28FEB1982	8.5	8.8	9.1	9.0	6.5	7.6	8.4	8.1	16.5	51	27
06MAR1982	7.6	19.4	10.6	19.2	9.7	21.6	20.1	9.3	29.4	57	43
12MAR1982	13.1	44.0	.	.	13.1	47.1	.	.	.	91	61
18MAR1982	27.3	38.1	.	.	25.9	34.4	.	.	.	111	71

TABLE 1.5

DICHOTOMOUS SAMPLING NETWORK DATA (ug/m^3) - Continued

Date	Sierra Manual (Coarse)	Sierra Manual (Fine)	Sierra Automatic (Coarse)	Sierra Automatic (Fine)	Andersen (Coarse)	Andersen (Fine)	Average of Fine	Average of Coarse	Total (Fine & Coarse)	HiVol	Size Selective Inlet
24MAR1982	39.9	32.0	39.9	30.2	36.4	30.7	30.9	38.8	69.7	120	80
30MAR1982	29.3	28.8	26.8	26.7	22.2	26.3	27.3	26.1	53.4	103	60
05APR1982	83.8	10.1	93.5	11.3	75.6	8.6	10.0	84.3	94.3	113	87
11APR1982	6.5	20.4	6.4	18.8	6.2	18.6	19.3	6.4	25.6	45	29
17APR1982	13.1	18.8	12.7	16.8	12.9	17.4	17.7	12.9	30.6	55	34
23APR1982	38.5	14.2	42.4	10.4	30.9	12.2	12.3	37.3	49.6	89	56
29APR1982	37.6	16.2	33.7	12.1	32.2	14.8	14.4	34.5	48.9	100	58
05MAY1982	35.7	21.0	37.0	19.6	29.0	17.7	19.4	33.9	53.3	100	62
11MAY1982	38.3	12.2	36.1	11.3	.	.	.	.	.	97	58
17MAY1982	31.4	13.6	31.9	13.2	.	11.7	12.8	.	.	86	47
23MAY1982	4.5	10.2	.	.	4.9	8.4	.	.	.	38	21
29MAY1982	18.1	29.3	16.5	27.9	14.2	22.0	26.4	16.3	42.7	69	47
04JUN1982	19.0	10.0	.	.	15.2	10.9	.	.	.	55	34
10JUN1982	24.5	32.0	.	.	21.2	26.1	.	.	.	86	62
16JUN1982	13.0	13.0	.	.	10.6	11.6	.	.	.	.	.

TABLE 2

SAMPLE STATISTICS

(Data in ug/m^3)

SAMPLE TYPE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
Sierra Manual (Fine)	117	18.0	11.9	2107.8	1.4	75.9
Sierra Automatic (Fine)	70	17.8	10.1	1245.4	0.3	49.8
Andersen (Fine)	83	17.8	10.7	1479.6	3.0	53.8
FINE (Average of)	60	17.6	9.5	1054.9	4.1	48.5
Sierra Manual (Coarse)	117	18.5	13.6	2158.7	0.0	83.8
Sierra Automatic (Coarse)	70	23.8	18.9	1668.6	1.3	93.5
Andersen (Coarse)	84	20.5	15.2	1703.8	2.8	75.6
COARSE (Average of)	59	23.1	15.8	1388.7	3.4	84.3
TOTAL (Fine & Coarse)	59	40.7	19.5	2399.5	9.3	94.3
Size Selective Inlet	106	46.6	19.3	4944.0	13.0	118.0
HiVol	118	65.0	27.2	7665.0	20.0	181.0

AR23-37

SP 01-02-07

TABLE 3

CORRELATION COEFFICIENTS BETWEEN SAMPLERS

	Sierra Manual (Fine)	Sierra Automatic (Fine)	Andersen (Fine)	Average of Fine	Sierra Manual (Coarse)	Sierra Automatic (Coarse)	Andersen (Coarse)	Average of Coarse	Total (Fine & Coarse)	Size Selective Inlet	HiVol
Sierra Manual (Fine)	1.00000	0.86917	0.91784	0.90261	0.32865	0.08354	0.06736	0.11340	0.53646	0.49164	0.49121
Sierra Automatic (Fine)	0.86917	1.00000	0.81490	0.89502	0.06672	0.07788	0.02451	0.10251	0.52390	0.49354	0.36508
Andersen (Fine)	0.91784	0.81490	1.00000	0.93950	0.12778	0.07835	0.14912	0.10486	0.54479	0.53494	0.52382
Average of Fine	0.90261	0.89502	0.93950	1.00000	0.12302	0.09267	0.14177	0.13123	0.59903	0.49176	0.44264
Sierra Manual (Coarse)	0.32865	0.06672	0.12778	0.12302	1.00000	0.79769	0.78971	0.91942	0.80632	0.65407	0.68850
Sierra Automatic (Coarse)	0.08354	0.07788	0.07835	0.09267	0.79769	1.00000	0.74582	0.93156	0.79991	0.66695	0.63702
Andersen (Coarse)	0.06736	0.02451	0.14912	0.14177	0.78971	0.74582	1.00000	0.90698	0.80247	0.72116	0.71483
Average of Coarse	0.11340	0.10251	0.10486	0.13123	0.91942	0.93156	0.90698	1.00000	0.87241	0.73784	0.71133
Total (Fine and Coarse)	0.53646	0.52390	0.54479	0.59903	0.80632	0.79991	0.80247	0.87241	1.00000	0.83836	0.79588
Size Selective Inlet	0.49164	0.49354	0.53494	0.49176	0.65407	0.66695	0.72116	0.73784	0.83836	1.00000	0.94082
HiVol	0.49121	0.36508	0.52382	0.44264	0.68850	0.63702	0.71483	0.71133	0.79588	0.94082	1.00000

Ontario
Ministry of the Environment
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Atmospheric Research and
Special Programs Section
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July 27, 1983

Mr. Jim Smith
Hazardous Contaminants and Standards Branch
40 St. Clair Avenue West
7th Floor
Toronto, Ontario

Dear Jim:

Re: Sampling and Analysis of Inhalable Particulate

Enclosed is the report "Comparison of Samplers to Measure Inhalable Particulate" outlining the Ministry of Environment study in this area. As a results of this research, we have deployed samplers in most major Ontario cities and inhalable particulate levels at a number of active sites will be measured and statistically appraised throughout the next year. These studies will assist in the setting of an inhalable particulate standard and provide the basis of a control strategy for inhalable particulate in Ontario.

MINISTRY OF THE ENVIRONMENT
JUL 28 1983
HAZARDOUS CONTAMINANTS
OFFICE

Yours truly,

John Hicks,
Research Officer

JH/mb/AR30-34
Encls.

(some light reading to put you to sleep at night. Hope all is well.)

TD
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1983